PROCEEDINGS

OF THE

National Annual Meeting

FOREST PRODUCTS RESEARCH SOCIETY

Research . Development . Production . Utilization

CIVIC AUDITORIUM
GRAND RAPIDS, MICHIGAN

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MONDAY, TUESDAY AND WEDNESDAY
MAY 2, 3 and 4

1949

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VOLUME THREE

FOREST PRODUCTS RESEARCH SOCIETY
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1949 NATIONAL ANNUAL MEETING

The technical sessions of the 1949 National Annual Meeting were held in the Black and Silver Room of the Civic Auditorium in Grand Rapids, Michigan, with the exception of Session—III, which was held in the Red Room of the Auditorium. The Forest Products Industry Show was held in the exhibit floor of the Auditorium. Technical Session—I was opened by President George A. Garratt at 9:30 a. m., Monday, May 2, 1949.

Registration

Registration was opened at 4:00 p. m., Sunday, May 1, in the lobby of the Pantlind Hotel, the headquarters hotel for the meeting. As in previous years, the meeting was open to all interested persons, whether members or non-members. A registration fee of $3.00 was charged to all who attended the technical sessions. During the three-day meeting a total of 654 persons registered for these sessions, thereby establishing a new record for attendance at a Society meeting. Admission to the Forest Products Industry Show was free, and an estimated 4,000 people visited it between 8:00 a. m., on Monday and 10:00 p. m., on Wednesday, when it was closed. The meeting drew representatives from 37 states, all provinces of Canada, and many foreign countries, including England, Holland, Norway, Sweden, Mexico, and the Hawaiian Islands.

President's Reception

An informal President's Reception was held in the Grand Ball Room of the Hotel Pantlind on the night of Monday, May 2. Close to 500 men and women attended this entertaining affair, which highlighted the social activities of the meeting. An unusual program of music was furnished by the Harmony Halls, one of Grand Rapid's nationally famous barbershop quartets. The reception was preceded by a cocktail hour in the Schubert Room of the Pantlind Hotel.

Field Trips

An outstanding selection of field trips was offered to the members on the afternoon of Tuesday, May 3. Several hundred took advantage of the opportunity to visit either the Haskelite Manufacturing Company, the American Seating Company, or the Grand Rapids Equipment Company. Tour groups left the Society's registration desk in the lobby of the Black and Silver Room of the Civic Auditorium at 1:30 p. m. and returned about 4:00 p. m. The trips were made by bus.

Ladies Program

In addition to attending the President's Reception, the wives who traveled to Grand Rapids with their husbands were kept busy with field trips on Monday and Tuesday afternoons. On Monday they visited the Grand Rapids Furniture Museum and on Tuesday inspected the show rooms of the John Widdicomb Co., the Widdicomb Furniture Co., and the Baker Furniture Co. in the Exhibitors Buildings, which are located directly across the street from the Civic Auditorium and the Pantlind Hotel. On Tuesday they had the additional benefit of being accompanied by an interior decorator on their tour.

Section Representatives Meeting

On Tuesday afternoon, representatives of all local sections met together for the first time to discuss problems common to all sections. Chairman of this meeting was John Sweeney, Chairman of the Midwest Section; the Secretary was Don Walters, Secretary of the Inland Empire Section. In addition to exchanging opinions and experiences concerning the operation of local sections, these representatives drew up a number of recommendations to be submitted to the Executive Board for possible action on matters of particular interest to the sections. It is planned to continue these meet-

ings as a regular part of future national meetings.

Tuesday Evening Dinner

An informal dinner was held on Tuesday evening in the Continental Room of the Pantlind Hotel for the men responsible for the operation of the Society and the handling of the Grand Rapids meeting. The National Officers, section representatives, and Committee Members attended this affair, which was preceded by a short cocktail hour. President Garratt spoke to the group briefly and thanked them all for their cooperation and hard work in making the meeting a success. The gathering was also addressed by Jac. H. Tigelaar, general chairman of the 1949 Annual Meeting.

The *Wood* Award

Presentation of the *Wood* Award was made by Herbert A. Vance, Publisher of *Wood* Magazine and President of Vance Publishing Corporation, Chicago, Illinois, during Technical Session—V on Wednesday morning, May 4. This $500 award, which is offered for the most outstanding paper on forest products research submitted for competition by a student currently enrolled in any university or college, was won by John L. Hill of the Yale School of Forestry. This paper is reproduced in this Proceedings in Technical Session—V. Second place in this competition was won by Ben S. Bryant, of the University of Washington and third place by John A. Rowe, Jr., of the University of Idaho.

Presentation of Papers

The general formula for the presentation of technical papers called for each author to condense his remarks to a ten-minute summary of his subject. This was then followed by a discussion period with comments from the floor. Preprints of as many papers as possible were made available to all who registered for the technical sessions. The complete papers, as published first in preprint form, are printed in this Proceedings. Immediately following each paper is given the discussion relating to it and the author's answer.

TECHNICAL SESSION I

Monday, May 2, 1949, 9:00 A. M.

General Subject: Raw Material and Its Preparation

Chairman: James F. Hamilton, Technical Service Director, Perkins Glue Company, Lansdale, Pennsylvania *(Second Vice-President, FPRS)*

Recorder: Robert W. Wellwood, Associate Professor, Department of Forestry, University of British Columbia, Vancouver, B. C., Canada *(Trustee, Pacific Northwest Section, FPRS)*

More Wood Per Acre

W. D. Hagenstein

Forest Engineer, West Coast Lumbermen's Association and Pacific Northwest Loggers Association, Portland, Oregon

Remarkable progress in forest management has been made on the 3,008,638 acres of tree farms in the Douglas fir region since the initiation of the tree farm program in 1941. By making intensive inventories, developing new markets, and aiding in the planning of operations that may include thinning, prelogging, relogging, and salvage logging, foresters employed by tree farms have contributed greatly toward improved utilization, greater production, and better forest management. Case histories of 12 company operations on tree farms indicate the extent of the improvement in utilization and forest management that has been achieved.

Introduction

THE 26-million-acre commercial forest belt lying between the Cascade Mountains and the Pacific Ocean from the international boundary south to the Oregon–California line is termed in all forestry literature as the Douglas fir region. About a quarter of the total raw material of the wood-using industries of the United States comes from this region each year. Forest management can provide this quantity forever. West Coast tree farms are giving impetus to such forest management on private lands.

Half the commercial forest lands of the region are privately owned. The balance is publicly owned and managed by agencies at every level of government. This paper is confined to forest management as it affects forest utilization on the tax-paying half.

The Tree Farm Program

In 1941 the forest products industries of the Douglas fir region, acting through the Joint Committee on Forest Conservation, West Coast Lumbermen's Association, and Pacific Northwest Loggers Association established the tree farm program by certifying a property in Western Washington of about 120,000 acres as the first tree farm in the United States. The origin, expansion, objectives, and methods of the tree farm movement are well described by Tilley *(4)*.

After 8 years, tree farm management has been extended to 3,014,141 acres of privately owned lands in the Douglas fir region. Of this total, 5,503 acres consists of 38 farm-owned properties. The balance of 3,008,638 acres comprising 51 properties averaging 58.973 acres is owned by 28 companies. This latter acreage is 27 percent of the non-farm ownership of the region. The industrial properties are owned and operated by an interesting variety of companies as set forth in Table 1.

TABLE 1.—OWNERSHIP OF INDUSTRIAL TREE FARMS IN DOUGLAS FIR REGION BY TYPE OF COMPANY[1]

Type of Ownership	Number of Companies	Number of Properties
Lumber Companies	15	19
Pulp and Paper Companies	2	12
Integrated Companies	5	14
Logging Companies	2	2
Non-Operating Companies	4	4
Total	28	51

[1] Type of ownership in this table refers to the wood use of the tree farm owner, e.g., a lumber company utilizes its timber for the manufacture of lumber and lumber products exclusively. An integrated company utilizes its timber for more than one product, e.g., plywood and lumber. The non-operating companies consist of railroad and timber holding companies, but the tree farms of all those listed are being operated by others under various contract arrangements.

It is interesting to note that six of the tree farms listed in Table 1 are cooperative ventures between two or more owners. Another interesting development is a cooperative forest management organization serving properties of six of these companies.

West Coast tree farm foresters, while making the usual forest inventories, have also recorded carefully and completely kinds, volume, and location of raw material, both in standing trees and logging slash, not normally tallied in commercial timber cruises. It is on these raw material data and their application that the writer wishes to report particularly.

Vinnedge *(5)* and Hodgson *(2)* have shown the sizeable volume of wood left on the ground following logging in the Douglas fir region. Kirkland *(3)* has estimated the raw material

possibilities from thinnings. The writer *(1)* has previously reported one outstanding example of complete utilization stimulated by a detailed forest inventory.

For the last 8 years, forest inventories on West Coast tree farms have determined the usable volumes of wood obtainable through some type of salvage logging,[1] whether it be relogging, prelogging, or thinning. In this way valuable business information is furnished to wood users who have plants requiring a continuing and steady supply of wood.

Case Histories

To illustrate the kind of information gathered by forest inventories and what can be done with it to improve utilization in the woods, a number of case histories from West Coast tree farms are presented.

An intensive forest inventory was begun by Company A in 1946 and completed a year later. The annual cut had been drastically reduced in 1945 because it was suspected that the property was being overcut. This was borne out by the detailed inventory, which showed an imbalance of young and middle age classes in relation to the acreage of mature timber.

Considerable volume of reloggable salvage was revealed by an earlier inventory on cutover lands. On a property of approximately a township in size salvage has averaged about 2,000 board feet log scale per acre each year since 1942. It is estimated that another 8 million board feet log scale will be salvaged before such possibilities are exhausted. This material is helping make up the deficit caused by curtailment of the annual cut of mature timber.

Company B completed its forest inventory in 1943. Relogging was instituted thereafter to salvage material that had been left behind as being unmerchantable. The inventory showed a large number of submarginal logs, which could not be profitably handled by the company's main operation but could be converted into lumber in the woods with a portable sawmill cutting 15 to 20 thousand board feet per day. This has changed the logging methods of the company so that marginality of logs in each setting is determined in advance and the logging conducted accordingly. This means much more complete utilization than was possible under previous methods.

This company is also obtaining a sizeable quantity of small products from thinnings in young Douglas fir stands. Smelter poles, utility poles, and pulpwood are yielded by such thinnings and everything is taken to a 3-inch top diameter. The proximity of this tree farm to an outlet for small products makes this possible. Other companies with similar stands unfavorably situated cannot do this at present.

The several tree farms owned by Company C were first inventoried in 1940 to determine the kinds and quantities of salvage wood obtainable. The survey was repeated in 1945. The result of these studies was closer utilization in subsequent primary logging and increased total volume per acre through salvage logging. On one of these operations 2 million board feet log scale was derived from prelogging alone in 1948. This operation employs a full-time forester who does nothing but check completeness of utilization on each logging setting.

Prelogging of small trees in old-growth timber occurred at another operation of Company C in 1948 and yielded 6 million board feet log scale. At another tree farm no primary logging has occurred for some years, but relogging is progressing continuously because the forest inventory disclosed a large number of merchantable values including old spar trees, snags, windfalls, and other leftovers.

Company D, which has its tree farm under contract to an operating concern, has found much marketable material on lands harvested during the past 6 or 7 years. The products obtained include peeler blocks, sawlogs, shingle bolts, fence posts, and pulpwood. The inventories revealed so many raw material values that postponement of slash disposal by the principal contractor has been requested until salvage has been completed.

This company has experienced excessive windthrow in some of its seed reservations. Salvage logging has therefore become standard procedure in reclaiming such windthrow. The most encouraging fact noted in this experience

[1] For good definitions and description of types of salvage logging see Grantham, J. B. "Salvage Operations in the Douglas-Fir Region: Their Present and Future." Oregon Forest Products Laboratory, Informational Circ. No. 1. 23 pp., illus. 1947.

has been that enough material can be salvaged from cut-over areas and seed source reservations by relogging, and by prelogging in old-growth stands, to pay all the forestry costs. Therefore, the company is planning salvage and reservation from cutting until mature of all its second-growth stands, which previously were subject to sale at any time. This proves the business value of the tree farm program.

Company E has completed intensive examination of 95 percent of its holdings and has located substantial salvage possibilities. Its forestry department has made specific recommendations regarding the harvesting of this material. After the inventory was partially completed, markets were developed for small products, such as shingle bolts, fence posts, and hop poles. A number of contractors have been engaged since in reclaiming this material which was passed over in the primary logging as being unmerchantable. In the last fiscal year 32 salvage sales were conducted on the property, which produced in excess of 5 million board feet log scale.

The company's inventory showed Christmas tree possibilities on some of its densely stocked low-quality timber producing lands and 27,000 Christmas trees were cut and sold from these lands in 1948.

From a business standpoint this property of more than two townships in size has operated its forestry department of five men, paid the property taxes, fire protection and all other forestry expenses for the last 2 years and has shown a revenue in excess of expense. This was done by utilizing the additional raw material revealed by the tree farm inventory without unduly disturbing the growing stock, which is the future raw material supply of the company.

Company F, whose plant is very close to its tree farm of a few thousand acres, studied its situation after completing its forest inventory. It decided several years ago that close utilization could be gained by keeping its clearcut logging settings 80 acres or less in extent and then falling every tree and snag. Utilization is very complete and everything down to 8 inches in diameter and 8 feet in length is taken. Very defective timber, which under commercial log grading rules would be culled, is hauled to the mill to reclaim the few pieces of lumber in it. If this company's timber were located twice as far away, the good utilization now attained would be impossible. Because of close utilization with one-phase logging, this company has had no need to resort to relogging or other type of salvage operation.

A tree farm recently organized by Company G began prelogging Western red cedar poles in its old-growth stands in advance of primary logging. Prelogging of Douglas fir piling in stands that contain this product is also planned. The forest inventory showed that a substantial volume of usable windfalls was being carried down a stream. They are now being salvaged as a special operation. Because of appreciable defect, the forest inventory of the tree farm included a very intensive quality cruise, so that advantage might be taken of market conditions by going into the low-grade stands when the market will absorb commodities produced therefrom.

Company H has recently completed its forest inventory and as a result has lowered its minimum log specifications to an 8-inch top diameter, 12 feet long. Logs are being taken that have a net scale of 25 percent if the scale is 75 percent clear or 35 percent net scale if there is 50 percent clear. A survey made in 1948 on recent cut-overs showed that 8 to 10 thousand board feet log scale more per acre is being recovered over logging of a year previous. Sampling showed that only two percent of the net merchantable volume per acre, or 1.6 thousand board feet log scale was left after logging in 1948. The company has been convinced of the practicability of returning to previously logged areas to reclaim the sound and merchantable portions of standing defective trees and of operating in small areas of forest previously left because of topographic inaccessibility.

Company I is no longer operating. However, it has maintained a substantial forest property and is managing it as a tree farm. This forest was examined in 1947 for the first time and has been producing high quality old-growth Douglas fir logs exclusively from windfalls and snags ever since.

This company's inventory includes very detailed notes on all possible utilization. Even though its property is situated in a region where there is very little hardwood, immature red alder and bigleaf maple are noted on each

tally sheet so that when these products become merchantable they will be removed. This exemplifies the type of utilization survey the company is making. Its inventory is so complete that at any future time it can give a reliable estimate as to the size and quantity of different kinds of raw material it will have available for marketing.

Several tree farms are owned and operated by Company J. Short logs down to 5 inches in diameter of both Douglas fir and pulp species have been removed from its forests for the last several years. Because of its very intensive forest inventories, this company has been getting excellent utilization from its old-growth timber and has been reclaiming important volumes from relogging. Thinnings have been started in the past three years, but are still somewhat experimental. On one tree farm 6,000 acres have been relogged since 1946. Surveys show that its clear-cutting operations in old-growth timber are now resulting in about 95 percent utilization of all merchantable wood.

On another property this concern has relogged about 3,500 acres and has a number of demonstration thinning areas. These experiments have set the stage and helped develop methods for the time when the company will make thinnings year after year on this property. On another tree farm the company has been logging insect-killed timber since 1944, and the utilization has been so complete that the slash has been released without burning by the state forestry department.

Company K, an integrated wood converter, has been logging for two years down to a top diameter of 6 inches, in lengths as short as 8 feet. Relogging possibilities were clearly shown in the company's forest inventory and this practice has been aggressively followed since 1945. Thinning has not been attempted as yet, but the inventories show the location and extent of the possibilities.

The physical timber and land inventory of Company L was completed in 1948. Its forester states in his report that the inventory has made it possible to formulate a sound forest management plan based on full crop utilization. This company recovered 1 million board feet log scale through relogging in 1948 on an area that had previously been considered unmerchantable. At another location a contract relogger followed the company's operation of a year previous. Production during 1948 of the contractor was over 4 million board feet log scale, or 26 percent of the total log input from the company's operation. The striking thing here is that the forest inventory showed for the first time the salvage opportunities. Using these data, the company at once undertook operations to reclaim this raw material. The implication of all this to the extension of the old-growth timber supply while building up the balance of age classes necessary for sustained yield forest management is highly significant.

This company also has learned that considerable windfall occurs in seed areas and is now attempting to prelog them to remove trees not deemed wind firm. This appears to be a new practice which has not been previously reported in the literature. It will undoubtedly become widespread as a result of the objective reservation of seed sources for natural reforestation on tree farms.

Summary

The case histories of forest utilization stemming from the opportunities for it as discovered by forest inventories made on tree farms show the importance of forest management to the wood-using industries.

Forest management, in most regions, must first overcome the fire problem, after which, the next logical steps are the adoption of cutting practices designed to obtain natural restocking, surveys to determine any need for artificial reforestation, and a complete inventory of the growing stock including age, species, grade and volume. The latter renders real forestry service when it points out the opportunities for more raw material from the same property—raw material which, in most cases, does not constitute an additional draft on the standing timber account. Until the advent of the tree farm program, practically no forest property in the Douglas fir region had ever had an intensive inventory of its resources. On the more than 3 million acres of industrially owned tree farms, three-quarters has been inventoried to the present. What has been done with these inventories in getting more wood per acre by reclaiming raw material once thought unmerchantable, or even non-existent, and effectively

extending the forest resources of the region thereby, clearly demonstrates the forestry value of West Coast tree farms.

Literature Cited

(1) Hagenstein, W. D. *The Balance Wheel of Industrial Forestry in the Douglas Fir Region.* Forestry Chronicle 19(2):79–86. 1943.

(2) Hodgson, A. H. *Logging Waste in the Douglas Fir Region.* West Coast Lumberman 56 and 57 (Suppl.):40 pp., illus. 1929.

(3) Kirkland, B. P. *Forest Resources of the Douglas Fir Region.* Joint Committee on Forest Conservation. Pacific Northwest Loggers Association and West Coast Lumbermen's Association. Portland, Oregon. 74 pp. 1946.

(4) Tilley, W. B. *American Tree Farms.* Journal of Forestry 42(11):796–799. 1944.

(5) Vinnedge, R. W. *Logging and Mill Losses in the Pacific Coast States.* U. S. Dept. Agr. Misc. Circ. 39:29–37. 1925.

Discussion

O. Harry Schrader, Jr. (University of Washington): Since the close of the recent war, private timber owners and operators have realized the absolute necessity of making the most complete utilization possible of forest raw material. In this paper, Mr. Hagenstein has emphasized the necessity for inventory studies and proper management policies as a prerequisite in attaining this goal.

Once the inventory has been completed, the next step involves planning for integrated utilization of the available material and a cutting plan to insure perpetual operation. Many factors will influence both the degree of integration and utilization that can be realized. The proximity of established wood-using industries, current market conditions, species and size of timber, area to be managed and topography all play an important part in determining the most practical and profitable methods to be followed. The "tree farm movement", now 8 years of age, can be credited as a catalyst for better utilization and timber management. The case histories of a number of tree farms as cited in Mr. Hagenstein's paper should serve to encourage all private timber holders to pursue scientific forest management. These successful tree farms may be regarded as pilot models, and the experience gained in their management will point the way to a more intensive practice of forestry in all of its phases.

Further extension of the available wood supply obtained from forested lands, resulting in still more wood per acre, may be accomplished by integrated wood-using industries. This would assure that leftovers from sawmill and plywood operations, for example, would become raw material for pulp mills, hardboard manufacture, other bulk fiber use, or cut-up plants. Progress in the wood converting industries in making better use of the raw material must accompany progress in timber management and harvesting.

Norman F. Smith (Michigan Department of Conservation): I would like to correct the impression which might be left by this paper that the tree farm system is confined to the Northwest. While it did start in that region, it has now spread to all parts of the country. A year ago Michigan became the twenty-second state to adopt the tree farm system.

R. W. Wellwood (University of British Columbia): The speaker, in summing up his talk, states that forest management must first overcome the fire problem. In the case histories discussed it was noted that in most, if not all, instances, the fire hazard was appreciably reduced because of the removal of so much inflammable material, previously left on the ground.

In addition, the fire hazard from human sources is also reduced. The psychological effect the word "tree farm" has on the residents of adjacent areas and workers in these forest areas, who can cause fires from carelessness and lack of cooperation, cannot be measured statistically, but is nevertheless very real.

The speaker states that the next logical step is "the adoption of cutting practices designed to obtain natural restocking." A result of the type of logging described is a seed bed left in excellent condition for natural restocking.

Tree farms have influenced not only technical forestry but also the forest industries.

Specialized equipment is needed in many instances for the harvesting of small material in what is predominantly a large-timber stand. Industries using such material frequently must adapt present equipment to handle it or devise new equipment. On the other hand certain specialized industries can obtain the type of raw material they prefer without competing in an open market with all other industries. For instance, a mill cutting barrel staves can obtain suitable stock from relogging operations where snags and windfalls are being removed. They are able to contract for only the type of wood they want without having to buy logs, sort out the ones they can use, and sell the remainder. Shingle bolts can be obtained in the same way.

The benefits of close utilization as practiced on the West Coast tree farms has certainly justified their existence and their further development.

C. D. Turley (Illinois Central Railroad): The railroads are extensive users of forest products and since the timber supply is steadily being diminished in this country, naturally the railroads are much interested in Mr. Hagenstein's paper "More Wood per Acre."

The solution is reforestation, proper forest management, and selective cutting. Tree farms are certainly a move in the right direction.

Emanuel Fritz (University of California): In spite of predictions of its doom and charges of insecurity by anti-industry minded critics, the "Tree Farm" movement continues to grow and prosper. It started in the State of Washington in 1941 and spread rapidly to the Atlantic seaboard. Belatedly it is receiving at least grudging notice by its detractors. It is safe to say that the tree farms are well on their way toward offering the best examples of large-scale forest practices in the United States. Equally significant is the large number of trained men employed by tree farm owners to manage their reforesting lands. The effect of applying the intense interest, imagination, and industry of these active young foresters is certain to be a "snow-balling" of the tree farm movement to even greater proportions and toward professional and operating standards that will eventually win public acclaim.

The setting up of tree farms has been accompanied by unexpected benefits. Mr. Hagenstein mentions in his paper how salvageable material was uncovered. Indirectly this discovery automatically calls the attention of the operating owner to the fact that while he was interested only in large sawlogs in the past he overlooked the utilization of smaller logs and chunks for other purposes. Now he is learning that trees do grow; that their annual per-acre growth is considerable; that trees lost in the process of natural mortality in unmanaged stands can be harvested before their demise for various profitable purposes, and that an acre of young growing timberland is an ever appreciating asset.

So now we see old-line lumber companies, once reviled as destroyers, interested in growing and utilizing anything from Christmas trees to veneer bolts. What they are doing today could not have been done in the past. Economic laws are inexorable. When it can be demonstrated that it pays to grow a forest, somebody will grow it.

About 35 years ago one of my engineering professors warned me of the risk in going into lumbering. Said he, "Wood is obsolete. You had better stay with the metals." Nothing is farther from the fact. Perhaps wood as lumber will be used less than in the past, but it will never be obsolete. Furthermore, vegetable fiber —a tree is merely a big vegetable—is a basic raw material and it can be grown as a crop. Its secrets are not yet all known but already wood fiber is being converted into a wide variety of products that have no resemblance to lumber. More are certain to come. With greater acreages of timberland steadily being put under tree farm management an ultimately adequate supply of this basic raw wood fiber is assured. The age of wood is not past; it is merely changing. In changing it will demand all the skill the scientist and technician can muster, because the forest products industries are no longer only the simple saw and shingle mills but pulp plants, hardboard plants, chemical plants, precision manufacturing plants, plywood plants and others.

E. G. Wiesehuegel (TVA Division of Forest Relations): Mr. Hagenstein has presented a most interesting discussion of the effectiveness of the tree farm movement on utilization in the Douglas fir region. In the South, as of the end of 1948, we had 1,251 tree farms with 10,827,897 acres, and the program is moving

forward very rapidly. We have no tree farms like the half-million-acre tree farm of the Weyerhaeuser Timber Company in Washington; many of those in this area are small, ranging from 15 or 20 acres upward, with most of them a few hundred acres in size. The problems involved in operating a tree farm in the South are quite different from those in the West.

I believe it might be wise for us to speculate for a moment concerning the reasons why this movement is proving so popular. I know that some believe it is a propaganda antidote for the possibility of Federal regulation which always seems to be impending. I do not think this is true, since the tree farm idea is simply a recognition of good practices followed in the past, and the promise that such practices will be followed in the future. It sets off those who are following practices which are generally in the public interest, and it is getting results from its psychological effect on other forest landowners through the examples and demonstrations afforded by the publicized tree farms. It is a measure of the success of past forestry programs conducted by state and federal agencies.

The individuals and corporations who are joining this movement are holding up their right hands and saying, "I have some land on which I am growing timber. I think it will be profitable. I believe it can be done without subsidy and I'll be glad to show my neighbors what I am doing." So, in effect, we are having a general show of hands for forestry, and sound cutting and utilization practices. The important thing is that this has come about by a process of education, which results in a voluntary decision on the part of each landowner and operator. The fact that there are a certain number of acres now in tree farms is, to my mind, much less significant than the fact that thousands of owners of woodlands are gathering around the standard of good forestry practice, with a desire to be so recognized, and are doing this voluntarily and without any compulsion.

In the Tennessee Valley area in seven states, the TVA is helping to promote this movement. In keeping with its policy of education and demonstration as one means to the achievement of sustained-yield forestry and improved utilization, it is assisting the states in obtaining recognition for those woodland owners who are doing a good job. It is proving to be a powerful tool for encouraging others to "come and do likewise."

Russell Stadelman (Nickey Brothers, Inc.): Signifying the South's participation in the "tree farm" movement, Tennessee now has 200 properties certified as official tree farms since joining the nation-wide program approximately two years ago. Most of these are small properties, since of 12,000,000 acres of woodland in Tennessee, over one-half of these properties are in small ownerships of 40 acres or less. Most of these are hardwood areas.

Raw Material Supply for Integrated Wood Utilization at Crossett

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The possibility of a sustained yield operation was recognized at an early date by the owners of the Crossett Lumber Company. Sound foresty practice was the first step toward realization of that goal. This was followed by the construction of a destructive distillation plant in 1930 to utilize low grade hardwoods interfering with the establishment and growth of pine. When it became apparent that the stands of young pine timber which replaced the virgin growth had developed to the point where thinnings were essential to maintain a suitable growth rate, a modern kraft paper mill was constructed in 1937 to use the thinnings and the sawlog tops left after logging. Thus with utilization assured, it has become the job of the foresters to mold the forest into an increasingly productive unit.

Introduction

AN ATTEMPT will be made to follow the development of the Crossett forest from its virgin state to its present condition through the influence of utilization and other factors including management. Since there are no published articles on this phase of Crossett's growth, the factual data has been taken from our files and the interpretation is based on the author's judgment.

The Forest and Its Development Through Management Policy and Utilization

The value of land for growing timber became a theme early in Crossett's history. It took courage and foresight on the part of the early management and the owners to plow back their earnings into the operation when others were cutting out and moving to new areas. Their ambition and goal has become a reality in the form of a sound sustained yield plan which holds more promise than did the early virgin stands because of the greater utilization possibilities that exist today.

Land acquisition was begun in the Crossett area in 1899 when timber was still considered by the settlers as something to get rid of so that farms could be made. When the company land office was opened, word got around among those wishing to sell their holding to "hurry up and sell before the damn fools run out of money." Choice virgin timber and land was sold at low prices and often purchased back by farmers after the timber was severed and the slash burned.

The first sawmill began operation in Crossett in 1902 and was followed by a second mill two years later. A third mill for the purpose of cutting hardwood was added in 1915.

The early market conditions, coupled with a desire to leave the land productive, brought about the decision to cut the timber to a 14-inch stump diameter immediately after the beginning of operations. This was a fortunate decision as many of the best quality sawlog trees being cut today grew from the stand that was left. Even though severely burned in the early days, those same trees provided the seed for trees that have since developed into pulpwood and sawtimber on the areas that were cut during the first twenty years of operation.

The early day loggers were not greatly concerned about fire and it was common practice to burn the slash as well as all of the woods. It kept the brush down and provided open working conditions in the woods. It might be well to add at this point that much of the early burning was actually beneficial in areas that had no reproduction. Hardwood development was thereby kept to a minimum for later seeding in of pine after forest protection was initiated. Parts of the virgin area that had one slash burn and very little subsequent fire have developed into some of Crossett's best stands.

After having made several trips south with his Yale Forest School classes, Professor H. H. Chapman in 1922 made a report to the Crossett management on loss through fire. His statement that $4,165,000 in fire losses had occurred since the company's beginning brought immediate action. A professional forester was hired along with four technically trained men to assist him. From that point on, fire protection was advocated and initiated

along with the marking of seed trees to provide for future regeneration. Land and timber purchases had been made largely with a view toward a limited run for the plants, but in 1923 an acquisition program was commenced based on the plan of a long term operation. That program has continued and is still in effect.

During the first World War a peak cut of 80 to 100 million board feet per year was reached. A year after his appointment as consulting forester in 1927, Ralph Bryant of the Yale Forest School proposed the first management plan for the forest. It was adopted in 1929 reducing the pine cut to 30 million board feet and the hardwood cut to 25 million board feet. This resulted in the abandonment of one sawmill.

The problem of contending with the hardwood growth on the forest was becoming evident. Fires, although beneficial in some instances, had repeatedly burned the pine reproduction on large areas, converting them gradually into predominantly hardwood stands of sprout origin. Hardwood sawlog utilization by early day standards was a "creaming" process which left a large portion of the stand in unmerchantable hardwood trees. As part of a far reaching program in timber stand improvement, the hardwood destructive distillation plant was constructed in 1930 to utilize trees with no future potential for sawtimber.

As the virgin stands were diminishing in area and volume, it became apparent that something must be done about cutting the second growth timber. The Southern Forest Experiment Station was looking for an area on which to conduct experiments in the management of young stands and came to Crossett with their proposals. In 1933 the company donated 1,680 acres of land to the Forest Service for the purpose of forest management research. Cooperation between the experimental forest and company foresters led to the adoption of selective logging on a portion of the company lands in 1934.

When the last of the virgin stands were logged, the old railroad logging system was abandoned. In 1937 the company holdings were divided into five forest districts, to facilitate selective logging by trucking equipment. The decision was economically sound as railroad logging was dependent on the heavy volumes characteristic of seed tree cutting in virgin stands. Contractors replaced company crews and that system is currently in effect.

Great areas of young timber had replaced the virgin stands. Old fields and other young stands were reaching the point where cordwood sized trees were dying out because of crowding. Sound forest management could not allow stands to go unthinned so it was decided that a kraft paper mill would be the solution for handling the by-product of these stands. Construction of a paper mill was started in March of 1937 and was completed in that year.

Ten years after the first management plan went into effect, a second forest survey was conducted by Dr. H. H. Chapman, who succeeded Ralph Bryant as consulting forester. The survey revealed that the first plan was sound and the forthcoming plan recommended that the pine sawtimber cut remain at 30 million board feet through the next ten years. It reduced the hardwood sawtimber cut to 22.5 million board feet per year and set the pulpwood cut at 40,000 cords annually.

As it became obvious that greater intensification of management was a necessity, plans were made in 1945 to subdivide the property into ten forest districts. That program was formally completed and activated in 1946 and 1947 as men and housing became available.

Effects of Policy and Management on the Forest

During the early years of operation the logging of the virgin forest had to conform largely with economic necessity. The markets were distant and only the highest grade lumber could be produced at a profit. As has been stated, this was a fortunate situation as a nucleus of smaller trees was left for the future forest. Some of the lighter virgin stands also contained patches of young timber for which there was no market.

Effect of Fire.—Repeated fires kept large areas from becoming satisfactorily stocked with pine and converted some stands into sprout hardwoods. Portions of the cutover land missed burning long enough to reach the size where fires did not destroy them and they are at present some of our better sawtimber areas. On the credit side of fire we have large stands of

pulpwood sized trees which came in after burning the slash on seed tree areas coupled with subsequent protection against fire. Intermittent fires in the virgin timber made logging easier by keeping the woods open and ultimately also served the purpose of making reproduction easier to obtain. We are currently faced with the problem of hardwood brush control on areas that are ready to be reproduced a second time.

Seed Trees and Fire Control.—Our first really effective forest management started when the policy of leaving seed trees was definitely established and fire control was tightened. This statement is made because we have a small area of virgin timber that was cut selectively and where fire was kept out. We definitely did not get the kind of pine reproduction that was anticipated, and we now have a problem area because of the great number of hardwood stems that took over the land. The above illustration points out that seed tree cutting followed by a fire and subsequent protection was an excellent method of handling virgin stands.

Land and Timber Purchases.—The acquisition program started in 1923 was a great factor in making possible the sustained yield cut advocated in 1929 and re-affirmed in 1939. The availability of virgin timber through 1936 and in moderate volume until 1940 was a great aid in allowing the second growth stands time to develop into merchantable sawlog sizes.

Condition of the Forest When Selective Logging Was Started

When the forest was subdivided into five districts in 1937, enough virgin area remained to supply approximately one-fourth of the cut for a period of three years. The balance of the cut was destined to come from second growth timber which had grown to sawlog size since 1902.

Log Size and Condition of the Sawtimber.—The log average in pine dropped to approximately 100 feet per log in the second growth stands as an effort was made to make an improvement cut in the first cutting cycle. Many of the trees were heavily fire scarred and badly formed after suppression in the virgin stand. Some defect through heartrot was also prevalent in the older trees. It was generally agreed that the first cut was to remove as many of the undesirable trees from the stands as possible and yet hold the cut to approximately one-third of the merchantable volume. A merchantability standard of one-hundred thousand board feet per forty acres of pine timber fourteen inches and over at d.b.h. was set up as a guide for logging.

Operable Area.—Less than one-third of the forest was considered to be operable and over fifty percent of the crown space was occupied by hardwoods. The best stands were well under ten thousand board feet per acre while the average operable acre was less than half that amount. The hardwoods were generally badly fire scarred and in small sizes averaging less than five hundred feet per acre in the operable area. The balance of the forest ranged from pure hardwood stands in the bottomlands to all variations of pine and hardwood mixture. During forty years of railroad operation, tie hackers had cut millions of the best white and post oak trees to provide the tie requirements for the logging railroad. Only a small portion of the area was considered as having satisfactory stands of pine.

Plant Requirements in Relation to Management of the Forest

The primary objective of forest management has been the growing of high quality pine and hardwood sawtimber. All of the other materials are being considered as by-products.

Sawmill

Since 1929 the sawmill has been receiving only the amount of volume that the forest could sustain and yet improve the stocking. The cut has been purposely heavy in hardwood so as to conserve the pine volume and to reduce the percentage of hardwood in our pine stands.

Chemical Plant

The chemical plant has functioned continuously since 1930 using a hundred cords of hardwood per day. Only inferior grade hardwoods are utilized for that purpose, cut largely from stands in which they interfere with pine growth and development. No attempt is being made to grow hardwood specifically for that purpose as we have an indefinite supply of that class of timber on our lands at present. The yearly capacity of 35,000 cords enables us to

remove low value hardwoods annually from some 10,000 acres of area containing pine reproduction of varied size and density. The grade of material cut in this operation makes it remarkably adaptable for removing the remnants of the old growth stands and the areas which came up as sprout hardwoods as a result of early burning. Fire can be generally stated as being one of the greatest deterrents in attempting to grow good quality hardwood on pine growing land. Fire scarring allows decay to enter the trees and the vigor is reduced to the point where poorly formed stems are produced.

Kraft Mill

Thinnings, sawlog tops, damaged trees in logging and mortality are the only source of pine pulpwood from our lands. Approximately ten percent of our annual cut of 40,000 cords from company lands is from gum growing only in pine stands. No stands are grown or cut with the idea of making pulpwood the final harvest. Some of our early plantations are now being thinned to yield pulpwood, but our greatest volume is coming from the operations listed above. Thinnings enable us to maintain a satisfactory growth rate and to leave the type of tree that will produce top quality sawtimber in quantity. The young stands prevalent throughout most of the south are in the process of producing great volumes of pulpwood but we feel that our advanced quality sawtimber goal will be a profitable proposition for the future as it has been in the past.

The remainder of our annual 200,000 cord pulpwood requirement is purchased to a large extent from neighboring companies practicing sustained yield management on their properties. Recognized cutting methods are being advocated by our pulpwood buyers throughout the rest of our procurement territory.

Present Methods of Management and Harvesting

The Forestry Division of the Crossett Lumber Company is in direct charge of managing the company owned timber lands and for delivering all of the raw material requirements to the various plants.

Regulation of Cut

The forest survey of 1939 is the basis from which the present volume of cutting was determined. The survey was made on a 0.625 percent cruise which was sufficient to get a good estimate of total volume and of great enough reliability to allocate the portion of the total cut which was to be taken from each of the five forest districts then in operation. As previously stated, an operability standard of 100 M board feet of pine fourteen inches and up at d.b.h. was set as the minimum requirement for logging. In turn the amount to cut from any given forty was determined from area-wide growth studies coordinated with the ultimate desirable goal of stocking. The regulation of hardwood cut is aimed primarily toward removing as much volume from pine areas as utilization standards will allow.

Cutting Cycle

We are tentatively set up to operate on a ten year cutting cycle but in practice the average span between cuts has proven to be closer to eight years. As new areas come within operability standards the cycle will probably lengthen to ten years.

Silvicultural System Used

Our first log cutting in any given area is made largely for improvement purposes removing fire scarred, badly formed, overmature, diseased, leaning, poor risk and slow growing trees from the stand. Not enough trees of this type are always found to remove sufficient volume for economic logging so the balance of the cut is made for spacing or thinning purposes. In our second selective cut we have found the timber to be of generally better quality and wherever necessary this cut is a combination improvement cutting, thinning, salvage and harvest cutting, all in the same operation, depending on the needs of the stand. Our constant aim is to secure reproduction as soon as it can develop under the existing stands. While we have not yet decided on the ultimate method by which to manage our lands, the present system of concentrating our operation on areas of good volume and cutting by the selection system is serving a twofold purpose. It is giving our unmerchantable areas time to develop and it is providing eco-

nomically sound logging operations which yield quality suitable for the existing market.

Harvesting Procedure

The production of logs, pulpwood and chemical wood, has been done largely by contract since 1937. To facilitate management and the production of forest products, the forest was subdivided into ten districts. The forester in charge of each district prepares an annual working plan based on a cruise of a given area capable of yielding the raw materials allocated to his area on a yearly basis by the company management plan. His plan also covers the various other duties which complete his responsibility in managing his district.

Logging Operations.—Most of the timber felling is still done with two-man cross cut saws, although power saws are rapidly gaining in popularity. One of the main reasons for this trend is the gradual passing of the old type sawhand and his replacement by younger workers who prefer more modern methods. Tractors have replaced teams for skidding work, and a variety of mechanical loaders are in use to load the trucks for transporting the logs to rail points or direct to the plant. Team logging with wagons is done only for the purpose of banking logs on all weather roads for use through the winter and on shows close to the railroads. Teams of horses or mules were the only means of bunching and loading trucks or wagons until 1942. Company operated logging trains running largely over commercial lines on a train mile basis bring the logs from railroad landings to the sawmill.

Pulpwood Operations.—Pulpwood contractors immediately follow the logger to cut wood from the tops, thinnings and damaged trees. The wood is either trucked directly to the plant or loaded on railroad cars for transportation to the plant. Mechanical saws, loaders and loading systems, and tractor skidding have largely replaced the old methods. We are currently doing intensive research work on further means of aiding our contractors to mechanize and improve their present systems.

Chemical Wood Operations.—The log and pulpwood crews are often followed by a chemical wood contractor to complete the treatment of the stand. The wood is cut and penned in the woods for a period of three to six months for air drying purposes before it is hauled directly to the plant or to rail points for shipping. Penning in the woods is necessary because green wood has a tendency to rot before it will dry in the yard stacks.

Present Efforts Made Toward Increasing the Productivity of the Forest

Our number one aim is to increase our pine stands and stocking to the point where our manufacturing plants can be completely and perpetually supplied with raw materials from our own forest.

Hardwood Control

Besides the chemical plant, we have small sawmills cutting lumber and cross ties from generally low grade hardwoods. A large scale girdling program is being carried out to rid the forest of cull hardwoods. Experimentation for a practical method of ammate poisoning is in progress. Gum is being used to a limited extent at the paper mill, and a plant to produce hickory handle stock was recently installed. Large areas of hardwood brush have been cut in cleaning operations to liberate pine. The old timers used fire effectively to control hardwood brush and we are also delving into its possibilities. While we do not hope or desire to ever cut the last hardwood, we are striving to reduce our hardwood canopy to twenty-five percent of the total on pine lands.

Protection

Great strides have been made in recent years through cooperation with the State force, which is primarily responsible and to whom we pay a fixed rate per acre per year for protection. A system of radio communication was installed in all State vehicles and two lookout towers during the past two years and each of our district foresters has similar equipment. Tractor-mounted State fire plows and company jeep and pull plows have combined to form very effective suppression units. A constant educational program is in progress and it is proving successful through schools, company sponsored barbecues, forest festivals and a rural baseball league for teen-agers.

Reforestation

During the past year over two million seedlings were planted with mechanical tree planters on 2036 acres of open lands. The shortage of nursery stock curtailed our program but we lifted and planted over one-half million wild seedlings. This was an experiment to determine the feasibility of using forest grown stock which had seeded in on an area after a heavy burn. Interesting information should result on the feasibility and success of using such stock. Seedlings are annually distributed free of charge to land owners within our forest and pulpwood procurement areas. Some of the early company plantings have already reached pulpwood size, and our local program will continue until the last open acre is productive.

Future Outlook

The general intensification of management will probably result in another breakdown of the forest districts into smaller areas as the forest becomes better stocked. A variety of silvicultural systems ranging from selection to shelterwood and seed tree cutting to reproduce even-aged stands is in prospect. In general we intend to treat each stand with whatever system will yield the greatest future return in the shortest time. We expect to improve woods mechanization, transportation and communication to the point where our raw material costs will be low enough to compete with our stiffest competitors. The critical period has been passed in our sustained yield plan and the future will bring greater production from our forest.

Discussion

Roy M. Carter (North Carolina State College): The accomplishments reported at Crossett can be duplicated by and between many other mills. They can be put into practice because I believe many mill managers recognize the value of integrated utilization but just haven't taken the time to investigate and follow through integration.

Integrated utilization is not restricted to plants who have a series of mills making a variety of products under one overall management such as at Crossett. Many communities have wood working plants whose raw material specifications vary although they are competing for their supplies. By better cooperation, and an honest effort on the part of the plant managers, the logs and timber more suitable for one mill than another could be exchanged. Materials that become unusable during manufacturing at one plant can be raw material for use at another mill.

The possibilities for integrated utilization are greatest in areas where raw material supplies for mills are acute. For example, in the northeast the timber supply for specialty mills is inadequate. In this area plants that require birch, ash, and maple for specialty products exchange soft wood logs and less desirable hardwoods, used by other mills, for hardwood. You also will find loggers who sort their logs by quality and ship them to the most suitable market. The veneer mills have been obtaining logs from many different types of wood-using plants which can get more for the veneer quality logs through exchange or sales than by using them in their own products. Recently some of these mills have found that their scrap is a partially fabricated dimension piece for some other mill. This integration does not always stop with the raw material. Some of these northeastern mills exchange finished products with other plants cooperating with them to fulfill orders. In reality integrated utilization could be termed cooperative utilization. Frequently the exchange was made after a number of years of cooperation with other plants.

One of the first prerequisites to integrated utilization, I believe, is the recognition by the varied wood-working plants, that they are not competing with each other since their products differ considerably. Their only competition is for the raw material supply. As long as they do not have an adequate supply it behooves them to exchange that material more suited to other products. The exchange of raw material between the smaller mills should be easier than between large mills due to the volume required. In actual practice, however, it is principally the large mills who have seen fit to practice integrated utilization. This should be reversed.

Our logging practice has been "cut the best and leave the rest". At Crossett the logging removes the poorest quality timber first in order to permit the best to obtain maximum develop-

ment. If this same method were practiced by other mills, we would not have this mad scramble for the high quality lumber and other wood products. We would be growing high quality timber rather than poorer and poorer quality timber. One step to obtain the desirable goal is to integrate utilization and thereby get rid of a lot of the poor quality timber now growing on our forest lands.

Mr. Sihvonen: The main difficulty that exists in duplicating Crossett's unique setup is the lack of a market for the low grade hardwood existing in abundance in this part of the South.

In making a broad statement, such as Mr. Carter's comment that "Integrated utilization is not restricted to plants who have a series of mills making a variety of products under one overall management such as at Crossett," one must bear in mind that truly integrated utilization calls for using all sound wood growing in a forest. With our varied use of wood we can take care of our pine, but the low grade hardwoods are growing faster than we can use them. Other companies in this region cannot do so well simply because utilization does not exist for the abundance of hardwood that is available on their lands. Since well over one-half of the available timber-growing land in this area is taken up by cull and nonmerchantable hardwood, the problem will continue acute as long as only the merchantable timber is cut and no utilization is found for the balance of the forest.

I agree with Mr. Carter that there is much room for improvement in the integration of the use for better grade material into products which will yield the most profit.

L. W. Hooker (Michigan College of Mining and Technology): It was my privilege to be a Forest District Supervisor at Crossett for several years before coming north to Michigan. The perpetuation of a raw material supply for an integrated wood-using industry such as exists at Crossett depends to a large extent on research to develop the techniques necessary to maintain the production of wood in the various forms needed. In this respect, Crossett is outstanding. Under Mr. Sihvonen's direction, extensive experiments are being carried out in such fields as planting, methods of cutting, and the use of fire as a silvicultural tool in the control of hardwoods in pine stands. In the latter field, Crossett has pioneered in the South.

The progress which is being made is possible because the management of the Crossett Lumber Company is convinced that intensive forestry is a paying proposition.

Mr. Sihvonen: Mr. Hooker's comments are correct and very much to the point on what we are attempting to do at Crossett.

To help achieve our goal of a fully stocked forest, not only the technique of knowing how to renew the merchantable portion of the forest resource is desirable, but more adequate and complete utilization of the existing nonmerchantable hardwood volume is necessary.

New Developments in Harvesting Sawlogs

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Much that is new has developed in equipment and methods for harvesting sawlogs in the war and postwar years. The author describes some of these new developments and discusses some of the problems experienced in adopting them. A forecast is also presented of further progress to be expected in the next few years. This report deals largely with the Northeast and the Lake States, regions with which the author is most familiar, although some excursions are made into the South and the West to describe developments that seem to have wide applicability.

Introduction

PRIOR to the recent war there had not been much progress in logging in the Northeast and Lake States for 50 years. There was a considerable reservoir of old-time woodsmen, content to live in rough camps far back from the road, and proud of their ability to handle hand tools and horses. This reservoir was continually being replenished by immigrants from Europe, particularly the Scandinavian countries and the Balkans.

During and since the war, labor shortages on the woods jobs have become acute. The old-time native woodsmen have been disappearing from the camps, and the flood of immigrants has dried up to a trickle. Young men from the local communities have shunned woods work. They are more attracted by higher paid, easier, and safer work in town.

The timber operators, desperate for help, have been casting around for a solution to this labor shortage problem. Increases in rates of pay have been tried, with only indifferent success. Industries competing for the labor supply were also granting pay increases. Improvements in logging camps, including better sanitation, entertainment facilities, and better access roads helped also, largely in reducing crew turnover. Some operators closed their camps, and ran buses over the new access roads to transport their labor from nearby towns.

There has been a tremendous increase in interest in any and all mechanical devices that gave promise of increasing productivity of woods labor. Such devices, if successful, would reduce the size of crew needed, make it possible to increase pay rates still further, and to attract to the jobs younger men who were brought up in a mechanical age.

The timber operators had to start practically from scratch in mechanizing their woods jobs. By and large, equipment manufacturers had given little consideration to the problems of operators in the Northeast and Lake States. The operators are typically small and poorly financed, and they are not organized in a way to make their needs known. The topography is rugged, and the stands are light, with relatively small timber scattered over a large territory. Woods labor had been contemptuous of mechanical equipment and on the few trials made had not given it a fair show.

Here and there some individual operators were experimenting with "Rube Goldberg" devices of their own invention and manufacture devised specifically to meet their individual problems. Some of these ideas had real merit.

Individual operators, and several organizations were instrumental in arousing interest among equipment manufacturers in the needs of the northern loggers. Among the latter were the American Pulpwood Association, the Lake States Timber Producers Association, and the United States Forest Service, first through its Timber Production for War Program, and later through its Forest Utilization Service.

A number of changes were made in logging methods and equipment during the war years. TPWP and the War Production Board, with which it worked, helped thousands of operators secure priorities to purchase scarce chain saws, tractors, and trucks. Local machine shops helped out by building, largely out of scrap parts, such devices as circular-saw slasher plants, logging winches and sulkies, and even small cable skidding outfits.

In the postwar period this development has continued at a more rapid pace. Many equip-

ment manufacturers with excess capacity resulting from wartime expansion, were actively looking for new products to manufacture. Young men returned from the armed services and the war industries, trained in the operation and maintenance of mechanical equipment, were looking for some business they could get into for themselves. Logging contracting appealed to many of them.

A variety of mechanical devices have been developed for every step in the logging job. Many of them are available commercially. Some have wide applicability; some are more specialized, and a few are "brainstorms" that are of limited usefulness. Development of such devices goes on apace. The old ones, like the chain saw and the logging tractor and its accessories, are being improved continuously. Scarcely a day goes by but that I hear of something entirely new that is in course of development or appearing on the market. Methods of logging are necessarily changing as new equipment and new ideas filter into the woods.

Let us try to describe a few of these devices and methods, roughly in the order in which they would be used on a woods operation.

Felling

First comes felling. For this operation the chain saw has proven to be far and away the most useful tool in our rough and rocky northern woods. The circular saws mounted on push carts or tractors have been highly successful in the more open and level pine stands of the South, but they have proven too difficult to get around and too dangerous under most conditions in the Northeast.

The postwar chain saw is a tremendously improved tool. The most popular models at present are powered by a self-contained gasoline motor. Two-man models available before the war weighed in excess of 100 pounds and cost about $700. Now saws of the same type, that will cut the majority of the trees on our sawlog jobs, are available that weigh only about 60 pounds and cost around $400. Because of improvements in design and in metallurgy, they are much more reliable and efficient cutting outfits.

The one-man, gasoline-powered chain saw is almost entirely a postwar development (Fig. 1). There are now seven makes on the market, and three or four more are about ready to be announced. Wartime developments have made it possible to build a gasoline motor that will provide up to 5 horsepower and weigh less than 20 pounds; so several of these saws are in the 30 pound range. They ordinarily are limited in cutting capacity to 18 or 20 inches, although in an emergency bigger timber can be cut with the models that have beavertail type blades. I have experimentally cut a 33-inch sugar maple with an 18-inch saw.

The bow-type frame has proven a tremendous improvement in cutting smaller timber (Fig. 2). With its narrow tapered guide bar, and the chain returning around the bow outside the cut, much of the pinching difficulties experienced with beaver tail blades are completely eliminated. I have cut down through a log suspended at the two ends, with six husky men perched on it, without any trouble from pinching. These bow frames are now available from several sources for both one-man and two-man chain saw models.

The electric-powered chain saw is more expensive, and a little more difficult to transport around with its heavy motor-generator unit than the makes with the gasoline motor mounted directly on them. But it is considerably more trouble-free. Electric power can take an overload without stalling, which gasoline power cannot. Electric motors are lighter in weight, freer from vibration, and the operator is away from the fumes of the gasoline motor. We now have a one-man electric saw, with a 14-inch cutter bar that weighs only 17 pounds. The motor-generator unit still weighs 129 pounds (Fig. 3). Some of our operators have mounted the heavier motor-generators for two-man electric saws on jeeps or crawler tractors and are using them successfully in the woods. The men like them very much, but there is a considerable investment involved in such a setup. By far the majority of our electric saws are being used in bucking at the landing, where transportation of the generator unit is not involved.

Skidding

The most important development in skidding is that the logging arch for use behind a crawler tractor has been scaled down to a size that fits Eastern conditions. These small arches,

Fig. 1.—One-man, gasoline-powered chain saw. Fig. 2.—Bow-type, one-man chain saw. Fig. 3.—One-man electric-powered chain saw. Fig. 4.—Small rubber-tired sulky for yarding logs. Fig. 5.—Tractor equipped with scoot and scoot loader. Fig. 6.—Cable skidder with hydraulic drive. Fig. 7.—Skyhook transporting logs. Fig. 8.—Bucking at landing with chain saw.

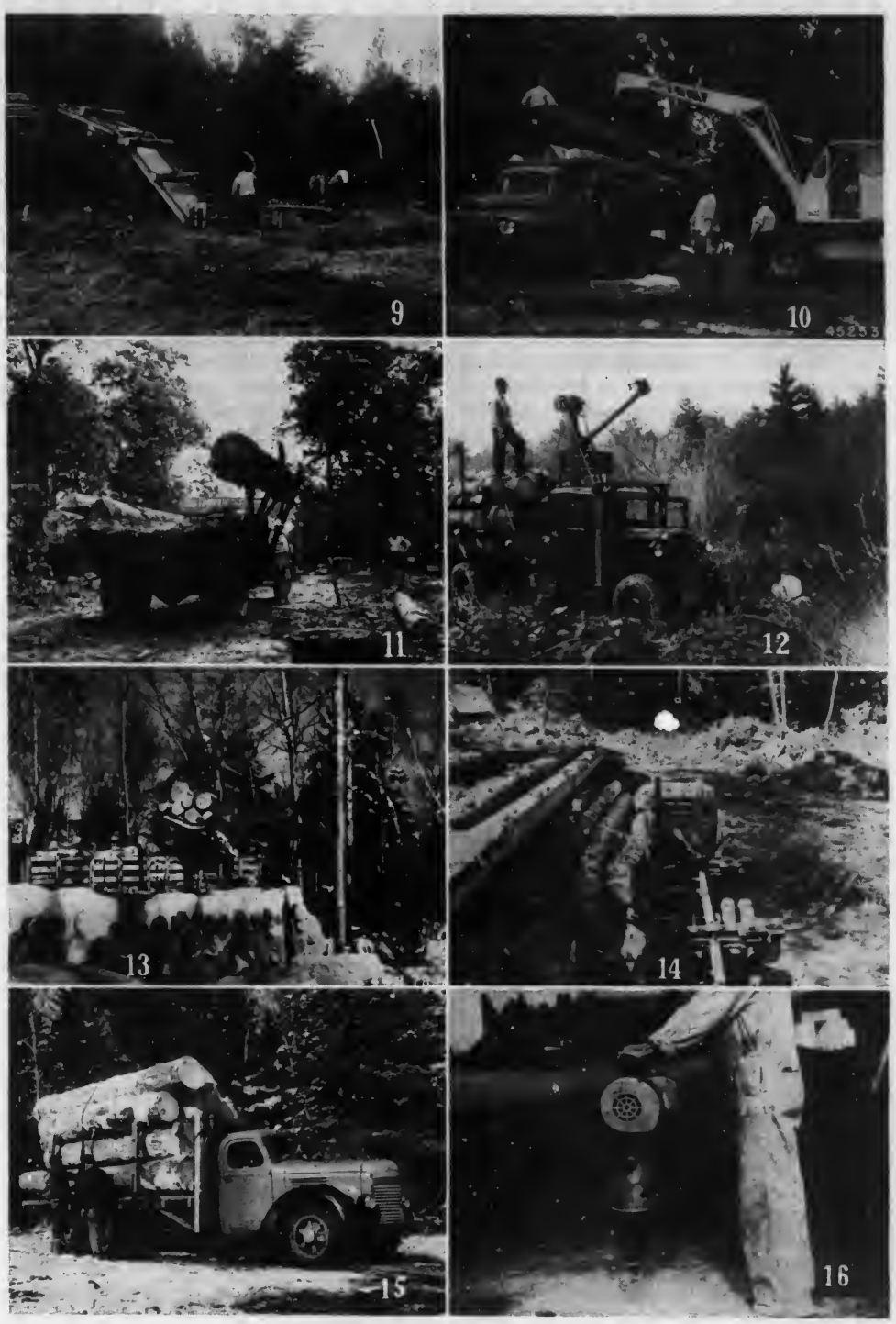

Fig. 9.—Portable circular saw slasher plant. Fig. 10.—Loading with revolving type crane. Fig. 11.—Timber Tosser loading logs. Fig. 12.—Truck equipped with jib boom skidding. Fig. 13.—Skid loader handling short bolts. Fig. 14.—Baldwin preloading system—transferring load to truck. Fig. 15.—Tandem axle truck with load of logs. Fig. 16.—English gasoline-powered portable rock drill.

most of them mounted on rubber, are available for tractors in the 30 to 50 horsepower range, along with really efficient and fully protected logging winches (Fig. 4). This combination is proving by far the most generally useful device for bringing timber out of the woods. With the cable running through a fairlead 8 to 12 feet above the ground the combination can effectively bunch its own load over a limited area, and then bring it to the roadside. Compared with ground skidding, friction and danger of hangups are materially reduced and up to twice as much volume can be brought in per trip. Tree length logging becomes possible with relatively small tractors, and the lengths are delivered to the roadside relatively free from embedded dirt and gravel.

This ability to transport tree-length logs is making bucking at the landing, which will be discussed under the next heading, more attractive.

Other skidding devices are also being developed or improved.

In glaciated sections, where highly abrasive particles are present in the dirt and gravel, wood-using industries are insistent on receiving clean logs. Consequently yarding with sleds or scoots is still popular in northern New England in summer as well as in winter. Scoot logging is also being mechanized. A number of operators have developed booms and winches mounted on the back of a tractor for bunching their loads and loading the scoots. One of these is now on the market commercially.

There is also a revival of interest in cable logging. Considerable high quality timber remains on rough and rocky slopes, or in swamps that cannot be logged with tractors, or even with horses. Improvements in wire rope and in its accessories and fittings in smaller sizes are making it easier to rig up light cable systems. Manganese steel choker hooks, swivels, clevises, and real loggers' blocks are now available from a number of manufacturers in sizes to handle wire rope down to ⅜ inch in diameter. Swaging and socketing supplies are becoming generally available and knowledge of their use is spreading. Preformed rope is easier and safer to handle. The hydraulic torque converter drive is giving internal combustion motors the ability to take shocks and overloads formerly possible only with steam power (Fig. 6).

Add to this a number of new systems of rigging recently developed both in this country and in Europe, and a whole new field is opened up for cable logging.

The Skyhook, which has the power unit and the operator in the carriage, is bringing logs and pulpwood out of the Carolina swamps, and even carrying tractors and other equipment back into these swamps, with less power, greater safety, and less interference from weather and water conditions than would be possible with any other method (Fig. 7).

Various systems of tightlining on high-lead installations are extending the usefulness of this simple and well known method of yarding. By use of a tightline on the haulback it is possible to lift rigging and even heavy loads of logs over obstructions a quarter mile from the skidder, with only a short spar.

Several systems developed in Switzerland during the war years, notably the Wyssen and the Lasso, promise to make it possible for even small operators to tackle jobs on steep and rocky slopes. Even more important, from the forestry standpoint, they promise to make it possible to bring out the wood with a minimum of damage to trees and reproduction saved for future growth, and to the soil on these steep slopes. Installations of both of these systems will be made in the Northeast during the coming summer.

Bucking

Bucking at the landing, or even at the using plant, is becoming more and more common. This has many advantages. It usually proves cheaper to buck at the landing, where the logs can be up off the ground on skids or in chutes, than it would be back in the woods. It is also possible to do the bucking more intelligently. A crew of bucking specialists, trained to get the greatest values in logs and other products out of the tree lengths, can be organized. Cuts can be more easily made at points of crook, whorls of knots, or places where other defects occur, thus producing logs of higher grade. Sections better suited for pulpwood, turning bolts, or even fuel or distillation wood can be recognized, and cut to the specifications for those products. On the other end of the scale high grade veneer logs can be cut and diverted to that use. Consequently greater values are ob-

tained from the harvest of the trees cut than if only standard logs had been cut with little or no regard for quality and the remainder of the tree suited to lesser value products left lying in the woods.

Several specialized mechanical devices have been developed for this bucking. The chain saws, especially the electric powered ones, are commonly used (Fig. 8). The chain type deck saw, powered by a standard electric motor, is coming into the picture frequently where commercial power is available. The wheeled circular saws have proven valuable in some cases. Drag saws are also being successfully used.

The most revolutionary, and in many instances the most efficient device, is the portable circular saw slasher plant, with some mechanical method for feeding the pole under the saw, for feeding the saw into the cut, and for carrying the cut lengths away (Fig. 9). A large number of such plants are in use in the Northeast and the Lake States. Most of them are home made. The pulpwood industry was probably the first to adopt them. The wood distillation industry found them the answer to reduction of its cutting and handling problems. More and more, they are being installed on integrated jobs, that produce logs as well as short bolt lengths. The sticks are brought in tree length and put on a conveyor, consisting of a chain, spiked rolls, or more and more frequently a fluted roll and buggy. This moves them forward into position for each cut. The circular saw is fed into the cut most often on a walking beam from above. Short lengths cut are picked up by another conveyor and transported to their place on the waiting railroad car, truck, barge or pile. Quality sections are run under the saw for 8-, 12-, 16-foot or other standard lengths, and the saw or veneer logs cut out pass over the short-length conveyor to a waiting set of rolls or skids to await loading out in their turn. Such plants, capable of cutting 60 to 80 cords per day, or the equivalent, have been installed at several locations. A few have been placed on the decks of sawmills.

Loading

Loading remains one of the most difficult problems of the northern logger. Revolving type cranes, mounted either on rubber or crawler tracks are becoming more and more common (Fig. 10). Most of them are being used with loading tongs at the center of the log, and the top loader, who is usually the truck driver, is responsible for catching the swinging, twirling log and guiding it to its place on the load. Loading is speeded up, bigger and better-balanced loads can be assembled, but the loading cranes are expensive and on most northern jobs they are idle a considerable part of the time. They also result in serious accidents, both to the top loader and the tong setter on the ground.

Crotch line and end dog loading rigs, with two men on tag lines attached to the dogs, are considerably safer but require an extra man. Heel booming has not become popular in this section as yet, probably because of the inexperience and unfamiliarity of most of the loader operators.

Many innovations are coming in in the loading field. One of the most successful, particularly for scattered logs, is the self-loading truck. There are three major variations of this idea. One is the Timber Tosser, with cradle arms at the side powered by a winch under the truck bed, which pick up the log and toss it over the side stakes (Fig. 11). This is an inexpensive and very efficient device, but its capacity is limited. Another is the jib boom, mounted in back of the truck cab and extending back over the bed. A cable from a winch mounted at the base is led up the upright and out to the tip of the boom. These are also limited in capacity, but a number of them are being used for skidding as well as loading relatively light logs (Fig. 12). The third device is slower, but less limited. This is the truck provided with its own crosshaul. A winch under the truck bed has a cable that can be brought out on either side, up over the bed and down to crosshaul logs up a pair of skids installed on the opposite side. These are being successfully used to load heavy sugar maple bowling pin and shoe last stock in western New York and Pennsylvania. A number of variations of these ideas are being tried. One operator in Illinois is hauling his load over a roller installed at the tail of the truck bed in packaged form with a winch mounted behind the cab. Some boltwood operators have installed a short jib boom at one of the rear corners of the truck bed. A device similar to the Timber Tosser, but with the

cradle arms powered by hydraulic rams instead of a winch cable, has been developed in New Brunswick.

Conveyor-type loaders, and packaging or bundling are largely confined to the pulpwood and short bolt field. The skid loader (Fig. 13), with its hydraulically actuated arms that can pick up as much as a cord of bolts is also primarily a short log tool, although one in New England has been handling hardwoods up to 16 feet in length around the yard.

There are several developments in the preloading field for sawlogs. One idea is to assemble the load with a crotch line or jammer on supports so that the truck can be backed under it. The rear end of the load is usually supported by a sturdy skid or cradle and the front can be on a bar mounted on hydraulic jacks or in a sling so that it can be lowered to the front truck bunk when the back bunk engages the rear portion of the load. A preloader has been developed in British Columbia that mounts the load on a pair of skids which are, in turn, mounted on inclined ramps, so that when the truck is backed under the whole thing can be slid down the ramps like a launching ship to its position on the bunks. This latter device, in smaller size, is now being manufactured in the United States.

One operator in Vermont has carried this preloading idea to a complete and efficient system (Fig. 14). He has equipped his logging trucks with roller chain conveyors on each of the bunks, powered from the truck motor. In the woods he erects a ramp and trestle, over which his crawler tractor and sulky can be driven. The load of logs behind the sulky drops through the slot in the middle of the trestle onto a pair of knees mounted on skids below. When a truckload is accumulated on these knees the specially equipped truck is driven up alongside, the chain conveyors engaged with the knees, and the entire truckload transferred to the truck bunks in about 20 seconds. At the mill the operation is reversed, and the load of logs is rolled off onto a set of skids in about the same time. The knees drop down between the skids, and they are picked up, put in a special receptacle on the truck, and returned to the woods.

Hauling

The motor truck is far and away the major means of transporting sawlogs in the Northeast and the Lake States. The modern logging truck is a much-improved means of transport, even over those that were available before the war. Since most logs are hauled in lengths of 16 feet and under, almost all hauling is done on the truck bed itself. Tandem rear axle trucks with power applied to both axles, are becoming the favorites throughout the territory (Fig. 15). Trucks so equipped are able to negotiate rough woods roads with a load, that could not have been traveled by single-rear-axle trucks when empty. A positive locking differential, which supplies power to any set of wheels that has traction, is a big help in this. A recent valuable innovation is a set of crawler tracks that can be installed over the tires on such tandem axles to give even more positive traction in mud or snow.

Front-wheel-drive trucks are being used in the woods to some extent, but have not been so popular because of the greater difficulty in steering and the lesser clearance under their differentials.

Trailers are not much used in this territory, except for hauling special products like piling and furnace poles. Many of the public roads are too narrow and crooked for effective use of trailers. But there is increasing interest in hauling material in longer than standard log lengths, especially by firms interested in integrated logging of tree length material. These tree lengths can be more efficiently bucked into a variety of products on the mill deck.

Another very valuable accessory for logging trucks is the hydrotarder, a hydraulic speed control device that saves the brakes in coming down sustained steep slopes. Developed to slow up airplanes landing on carrier decks during the war, it uses plain water in a hydraulic centrifugal pump arrangement, attached to the drive shaft, to hold the speed of the truck to a preset maximum. It is being manufactured and marketed by a West Virginia concern, and has found a place on western as well as eastern operations.

Another very important modern log truck improvement is the safety trip stakes now almost universally used. Formerly the log truck

driver had to knock out the stakes, or a fid hook holding them, from the same side on which the logs rolled off. The new stake trips, of which there are many models, all are released by a pull on a lever located on the opposite side of the truck. These tripping devices are eliminating many serious injuries that were incurred with the old type of stakes.

The construction of logging roads is also being made easier and cheaper. The crawler tractor with angledozer blade is still the most generally useful tool for woods road construction, but postwar models have many improvements. The horsepower ratings of postwar tractors have been increased; steering boosters are making their control easier on the operator, and the bulldozer controls are more efficient and the blades sturdier. The hydraulicly operated blade is the favorite on eastern operations because it has power behind it when it is lowered as well as when it is raised. This makes it possible when the tractor becomes mired to put a couple of poles under the blade, and then with a downward push on the blade to raise the front end of the crawler tracks enough so that skids can be placed under them over which the tractor can come out under its own power.

Other roadbuilding equipment that is proving valuable in the woods includes new models of light, gas-powered shovels, rippers, road maintainers, and rock crushers.

New explosives are an important part of the picture also. There are specialized types that are much more nearly foolproof for almost every job in the woods, from clearing overburden and stump removal to cracking rock ledges and throwing up a fill across a swamp. Important in extending their use are the new portable rock drills. A Pennsylvania concern has introduced a small self-powered compressor on crawler tracks, that can do a variety of woods jobs. From England has come a self-contained, 90-pound, gasoline-powered rock drill that automatically rotates the drill and blows out the hole (Fig. 16). New tungsten carbide tipped rock drill bitts have multiplied the life of this important tool up to 100 times.

Problems of Mechanization

Effective mechanization of the woods job calls for much more than just buying new equipment and sending it out to the crew. Many of our logging operators have learned this the hard way. Choice of the proper tools for the particular conditions to be met is important, but equally important is the selection and training of the men who will operate them, and alteration of the methods of operation to use these new tools most effectively.

Some reference has been made to these problems in the descriptions of some of the devices now available which have just been given. They are worth more emphasis.

Many timber operators have bought a new device, such as a chain saw, given it to one of their regular felling crews, and been disappointed in the results. The most successful and efficient chain saw crews are those that have been selected and trained for the job in the particular type of timber to be cut. Generally a young man, with some mechanical background and interest, has proven the most successful on the motor end of the saw. Such a worker is much more likely to keep the saw properly maintained and lubricated, and to be able to make necessary minor repairs on the spot. In many of the most successful cases the chain saw operator owns his own tool so he feels a proprietary interest in its maintenance. Sometimes an old-time logger, who knows a lot about the tricks of getting trees down successfully, and who is willing to learn new ones, proves to be successful on the tailstock of a two-man saw. Then, in most cases, it has proven desirable to add a third man to the saw crew. He can do the brushing out, wedging, and other axe work necessary to keep the saw running steadily, and he can transmit signals between the men on the opposite ends of the saw. He is available to fill in on one end of the saw in case of fatigue or injury, or when there is absenteeism.

Then it has proved desirable, particularly in young softwood stands where there is a great deal of limbing to be done, to add one, two, or even three additional axemen to the crew, in order to keep the saw running steadily. Such a crew, tailored to the job to be done, has proven in almost every case able to double man day production records previously attained with hand tools.

The same principles apply to the selection and organization of skidding, bucking, loading, and hauling crews.

Gearing a mechanized operation so that each phase keeps working steadily and in pace with each other step is a difficult proposition. Bottlenecks are continually developing. Breakdown of a skidding tractor may be as serious as loss of four or five teams from an old-time hand and horse job. Consequently, in addition to good operators, good mechanics and facilities for maintenance and repair are necessary. The fortunate operator has these available from his local distributor, and an aggressive and well-equipped local distributor should often be the deciding factor in choice of the particular make to be purchased. The less fortunate operator, far distant from a town or with a great deal of equipment to maintain, will establish his own well-equipped and manned maintenance and repair shop, and see that it has the facilities and authority it needs.

Needed Further Developments

As intimated several times, the revolution in our logging methods and the equipment used for them is far from complete. Practically every device used in the woods needs further improvement, and such improvements are being made continuously. Much progress has been made in recent months on the design of cutting teeth for the chain saw, on logging tractors and their accessories, on loaders and on log trucks. Many new ideas for improvement of these tools are fermenting in the minds of the operators and the manufacturers.

There are some fields, however, in which the need for development or improvement is particularly urgent.

One is the need for a really portable and efficient debarking machine. Most of our pulpwood, of course, must be free of bark before it goes into the chippers or grinders. Lack of a portable debarker is costing the pulpmills large sums each year in transportation of unwanted bark long distances to the barking facilities at the mill, and then disposal of the bark after it is removed. Saw and veneer mills are interested in debarking also. Debarked logs can be sawed more intelligently because defects are more visible, and less sharpening and breakage of saws is experienced because abrasive dirt and gravel are removed with the bark, and much embedded metal becomes visible. Then the waste from the sawing operation from debarked logs becomes more valuable. Slabs and edgings minus the bark are marketable at almost any pulpmill. Sawdust which is bark-free has greater possibilities for woodflour or other profitable uses.

Much work is being done on portable debarking devices. Pounding hammers, friction, and even hydraulic jets in various forms are being tried, but nothing that really meets the needs has been found. The most promising at present is a recently imported Swedish idea. Log lengths are run straight through a revolving disc across which chains under tension are so stretched that they embrace the log and take the bark off. This machine has been redesigned to American standards and is now on the market. A special trailer has been designed to carry its 10-ton weight to make it something of a portable tool. The cost is in the neighborhood of $35,000 and the capacity is about 5,000 linear feet an hour so it is a tool for the large, instead of the small operator.

Another field in which much further developmental work is needed is devising equipment for the very small operator, including the part-time farmer-logger. Although much of the equipment previously discussed has been scaled down both in price and in size in recent years it is still too big, too specialized, and too expensive for most of these small operators who get out a large proportion of our timber each year and who should get out more. A recent survey indicated that the farmer is spending four to five times as many may days for each unit of timber produced on his logging jobs as the good commercial operators. The difference is largely due to the equipment and methods used.

There are possibilities in the development of logging accessories for the equipment the farmer already has. A recent example is a rear-mounted winch with built-in fairlead for a wheel tractor. The truck tracks previously described are another.

In some cases the solution will have to be a new multipurpose machine suitable for use both in the woods and in the fields and orchards. The new light gasoline-powered crawler tractors are an example. A chain saw

with a detachable motor that can also be used in running a grinding wheel, a corn sheller, or similar device, is another.

Among the equipment most urgently needed by these small operators at the present time are the following:

A light portable and efficient debarker for pulpwood and fence posts.

A portable slasher saw. Several home-made models have been quite successful.

An inexpensive conveyor-loader for fuel and pulpwood.

Light, easily managed, and inexpensive cable logging systems. The Lasso cableway, from Switzerland, has possibilities.

With the generally awakened interest in such developments, I believe we can look forward to a great deal further progress in the next few years.

Discussion

H. E. Horton (The Prescott Company): We have followed with great interest the research done by Mr. Simmons. We have contributed at his invitation some data for compilation of his several papers, and we have, through his courtesy, a complete file of his treatise concerning logging in the northeast.

We consider that Mr. Simmons' work has been of great benefit to the loggers of that section. He has advocated the use of modern labor saving machinery, stressing utility with safety, and we believe that his recommendation should be seriously considered in the harvesting of logs.

Mr. Simmons has also commented at various times upon the inadvisability of manufacturing lumber with unsubstantial and inadequate sawmill machinery. Here, again, we believe that Mr. Simmons is definitely on the right track. We have no hesitancy in expressing the opinion that a goodly amount of lumber is butchered by the so-called ground rattler sawmills, which lumber would have secured a much higher price because of better grades, if it were properly manufactured.

Mr. Simmons: Thank you very much Mr. Horton for your laudatory comments. It is true that the lumber business has been grievously afflicted during the war and postwar years with the haywire sawmill and the haywire sawmill operator. Neither has much of a place in the competitive markets of today or the foreseeable future. The poorly cut, poorly dried, and poorly graded lumber they turn out has, to some extent, given all lumber a bad reputation. The marketing practices such mills follow has contributed to the chaotic condition of our lumber markets. Under today's conditions such firms must correct their practices and improve their equipment or drop out of the picture. Together with the trade associations and the equipment manufacturers we have been trying to help some of them do the former. Many of them are doing the latter.

Leland W. Hooker (Michigan College of Mining and Technology): Mr. Simmons has pointed out that there is still great need for suitable debarking equipment despite the fact that the subject is receiving much attention in many quarters.

At the Forest Products Research Division, Michigan College of Mining and Technology, we are undertaking an investigation to determine the feasibility of providing to the man who peels by hand a power-operated tool that will increase his speed and efficiency and will permit him to peel logs both before and after the normal summer peeling season. It is our belief that present lines of attack on the debarking problem leave a considerable gap between hand peeling and the use of heavy machines. It appears that the filling of this gap deserves considerable attention.

Mr. Simmons has indicated the several advantages in the use of logging arches and sulkies scaled down to fit Eastern conditions. I would like to bring to the attention of the group an objection to the use of sulkies and arches which has recently come to the fore in northern Michigan. Some land-owners are prohibiting the use of such equipment in their properties because they feel that it causes excessive damage to the residual stand when selective cutting is employed. Because of this objection, our division has instituted a study comparing logging damage in tree-length skidding with that in conventional tractor ground skidding. Early indications resulting from this study are that sulky skidding can actually be less injurious than the conventional method.

Mr. Simmons: I wish Lee Hooker and his colleagues success in their efforts to develop a

truly portable debarker. Let us hope that they, or someone else, will come up with one that will handle hardwoods as well as softwoods, and woods in the late summer and winter, as well as in the sap peeling season in the spring.

I have also been tremendously interested in the studies that have been made in northern Michigan on damage that has resulted on ordinary commercial operations, using different methods of skidding. There are undoubtedly some inherent differences in the results of these different methods. Even more important, in my opinion, is the way the equipment is handled and the attitude of the workers. I have seen some very destructive horse logging jobs, and some cable skidding operations on which the damage was negligible. The difference was in the layout and methods adopted by the operator, and the instructions and training given to the labor.

C. D. Dosker (Gamble Brothers): Why were pictures of the Jackson Harvester not shown? In my opinion this is an outstanding piece of sawmill equipment for the utilization of timber on scattered tracts.

Mr. Simmons: As mentioned in my informal introduction, the moving pictures shown were taken at the equipment demonstration we sponsored in cooperation with the New York Section, Society of American Foresters, last fall. Unfortunately the makers of the Jackson Lumber Harvester, as well as the makers of several of the other types of mobile mills, were not able to bring their equipment to this show. A number of them, including Jackson, were invited. I agree with Mr. Dosker that these mobile mills constitute a notable advance in making economically possible the utilization of timber on scattered tracts. There is a growing interest among commercial operators in converting logs into cants or flitches on such mobile mills. These can then be transported to the main mill for remanufacture much more cheaply than the round logs.

R. D. Carpenter (U. S. Forest Service): A one-man sawmill has been developed by the Corinth Machinery Company at Corinth, Mississippi and is in actual operation by the Davis Lumber Company at Cullman, Alabama. This mill is completely hydraulic. All of the features, including carriage feed, setworks, dogs, and log turner, are all hydraulically powered and controlled by the sawyers.

Mr. Simmons: The Davis sawmill is one example of the notable labor saving improvements that have been made in sawmills in the past few years. The West Coast Lumberman recently ran a cartoon showing a picture of a sawmill bearing the sign "No-man Sawmill—Employees Keep Out". We have not quite progressed to that point but there are several so called "One-man sawmills". Another one has recently been put on the market by a Hackettstown, N. J. sawmill machinery manufacturer. This uses mechanical means to automatically turn the logs, dog them, and advance the setworks. Some of the newer mills even have horizontally mounted edger saws, mounted ahead of the headsaw and controlled by the head sawyer.

E. W. Fobes (Forest Products Laboratory): Considerable attention has been given by Mr. Simmons to descriptions of available logging equipment. For the most part the basic principles and machines are not new, but do include improvements, application of advanced engineering design, and other details that can be summed up as modernization.

The question is, why this sudden splurge to mechanize logging? The answer is, to catch up with progress. Mechanization of logging is long overdue since progress has been falling behind that in other industries.

The reasons or excuses used by the lumber industry have often been that suitable equipment was not available. Mr. Simmons' paper points out the fallacy of this statement and shows what can be done when the industry decides to do something about it. The variety of available equipment is greater than the knowledge of its economical application.

Even with the equipment available, industry, as pointed out by Mr. Simmons, attributes lack of progress to the kind and attitude of woods workers. Basically, the reason goes beyond that, and is found in the psychology of the whole industry from top to bottom.

Before the war newcomers in the industry were few. By and large personnel was composed of men who grew up in the industry. Vacancies in the front office were filled by men from the woods. Consequently their attitude

toward mechanization was similar to the men they left behind.

That condition existing for a considerable period before the war created circumstances that forced management to introduce and develop equipment that did not appeal to it. Officials were not sold on equipment usage and made little, if any, effort to sell it to the men who were expected to use it.

Such efforts met with little or no success except in isolated cases, but these were outstanding enough to expose the potentialities of mechanization. Since then progress has been rapid and to some extent men with mechanical and training experience have taken over some of the supervisory positions.

Will progress in mechanization continue or has a temporary peak been reached similar to that following World War I? Indications are that the time has come to determine the best economical application of the array of equipment described by Mr. Simmons and continue mechanization efforts to keep the logging industry on a par with others so it will appeal to high quality workers.

Mr. Simmons: Gene Fobes is right when he says that there has been considerable resistance to mechanization and modernization of logging in top management as well as among woods laborers. In our territory the greatest advances in mechanization have been made and the most efficient operations are found, among what we consider medium-sized operators. These will cut somewhere between 20 and 50 thousand board feet of sawlogs, or between 50 and 100 cords of pulpwood a day. Many of the young ex-GI's, referred to in my paper, are in this class. They are big enough to be able to afford and make efficient use of much of the equipment that is currently available, and small enough so that the boss can be familiar with and work with every detail of the operation. He can usually pick and train his own labor, and make changes in personnel and methods whenever bottlenecks develop. In bigger companies the supervisory force on the ground has frequently not had the necessary interest or incentive to do this, and top management has not had the intimate knowledge or contact to be able to insist that it be done. Suitably priced equipment of a capacity needed by really small operators has not been generally available.

Confronted with the example of more efficient operations in the medium sized range, big companies are now actively trying to follow their example, or giving up their company jobs and contracting the work out to mechanically minded jobbers. Equipment manufacturers are becoming more interested in the market offered by the little "one gallus" operator, and more and more equipment suited to his needs is appearing on the market.

George J. Carr (Pacific Car and Foundry Company): Methods of sawlog harvesting are seriously influenced by the "abrasion factor" or sand, grit, and dirt picked up in the tree bark during the transportation cycle from stump to sawmill; particularly in the off highway or skidding operation.

The adaptation of West Coast logging methods (tractor-arch and high lead skidding) to saw log harvesting for portable sawmills would be facilitated if a sawmill had some device for cutting a kerf or "cleaning a path" for the mill saws. Is such a device available?

Mr. Simmons: George is right. This "abrasion factor" is particularly important in glaciated country, such as northern New England, where the soil is full of quartz crystals and other very hard particles. One New England manufacturer, the Dutton Lumber Co., at Brandon, Vt. has developed just such a device as George is looking for. It is a powered cog wheel, mounted on a walking beam, that the operator can pull down on top of a log to clean a path ahead of the saw cut. It is being successfully used in three of their mills, and Mr. Dutton is planning to manufacture it commercially. Other operators object to it however, since it throws a lot of dirt and shredded bark into the air. Several means of minimizing this trouble are being tried. A similar device has recently been put out by the manufacturers of the Jackson Lumber Harvester.

Status of Portable Wood Chippers

E. W. Fobes

Forester, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

Considerable development work has been done and a number of portable chippers suitable for chipping small wood have been developed and are in limited use for the reduction or disposal of prunings by city park departments and in the production of chipped wood for crude fiber products. There is need for chippers capable of handling larger wood and for debarking equipment that would operate in conjunction with the chippers to produce cleaner chips with a lower bark content.

Introduction

MECHANIZED timber harvesting has reached a stage of development in the United States that indicates certain advantages to be gained in forest management and utilization by the use of fragmenting equipment commonly called portable chippers. The underlying purpose of the use of such equipment is to reduce the handling of individual pieces of wood. The common thought is that the cost can be lowered through chipping at or near the source of wood supply because chips can be bulk-handled with blowers, conveyors, and other powered equipment better than miscellaneous forms and sizes of rough wood.

The Forest Products Laboratory, in the course of its investigations of more efficient timber harvesting methods, has recently made a survey of the present status of commercial chippers, the types of equipment available, the problems encountered, and the practical aspects and prospects for substantial extension of this method of wood conversion.

In general, it was found that, though of much current interest among timber operators and foresters, movable machines for converting rough wood into chip form are still in the development stage. Progress is not advancing so fast in connection with the utilization of the chipped wood and its application to forestry as it is in other applications, notably that in horticulture for shade tree and orchard brush disposal. This is challenging but not surprising when it is realized that the latter field probably involves larger margins for reducing high labor costs than are applicable to utilizing wood waste for a merchantable commodity.

[1] Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

Strictly speaking a portable chipper is one mounted on the same frame as the power supply and requiring, at most, only the disconnection of the conveyor system when it is moved. When such a unit is mounted on a vehicle it should be classed as a mobile chipper. When the chipper itself can be moved as a unit but requires separate handling of the power unit, disconnection from the foundation, or other similar dismantling, it should be termed semiportable.

Although the term "chips" is commonly used to designate the types of fragmented wood, among the wood-using industries several classes of wood fragments are recognized. It is important to draw fairly sharp distinctions between these classes, especially the two major types of wood fragments, namely, (1) chips in the technical sense, and (2) hogged wood. Table 1 gives a brief summary of the various kinds of chips, and their uses and specifications.

Among the first efforts in the United States to develop mobile chippers were those mounted on railroad cars. One was used in the Lake States in the late 1920's to produce chips for wood distillation. A more elaborate one was designed on the West Coast in 1929. It was complete with associated pulp-mill wood-room equipment, including saws, splitters, and disk barkers. The wood room with its problems was in effect merely transported to the woods where additional problems were added.

About 1940 in the Southeast a standard disk chipper with power supply mounted on a steel-wheeled trailer was used to chip pine tops and trees left by pulpwood loggers. Later a similar operation was tried on the Gulf Coast. More recently a truck-mounted chipper has produced chips for roofing felt mills in the Northeast. These operations were designed to produce uti-

lizable chips. However, during this same period a mobile chipper was developed in the Northeast to dispose of trees killed by the Dutch elm disease. From this came the present-day mobile chippers used for brush disposal.

Chipping of brush along power line right-of-ways has been found to minimize extra handling of small material, the need for burning crews, the danger of escaping brush fires, as well as dependence upon favorable weather conditions. Similar considerations are given to disposal of thinnings on at least one municipal watershed. A few horticulturists have found the use of a mobile chipper well worth the investment in disposing of orchard trimmings and improving the soil in sandy areas. Chips disintegrate and return nutrients and humus to the soil quicker than do brush piles and tree tops.

Concurrent use of semiportable chippers and hogs to produce utilizable chips has increased at permanent sawmills and railroad sidings. Slabs, edgings, and round wood are being chipped for roofing felt mills and other industries.

From the foregoing it appears that mobile equipment is especially applicable to thinnings and intermediate crops since the manual handling of small round wood is very expensive. Mobile or portable chippers should also find wide use in the salvaging of slabs and edgings produced by portable sawmills.

Available Equipment

Types of chipping equipment available today can be classified as (1) disk chippers, (2) cylinder chippers, and (3) wood hogs. In addition, hammer mills and shredders also produce wood fragments. Any of these machines are or can be made portable and mobile, while most of the chipping equipment can be adjusted or modified to produce uniform chips.

Disk Chippers

Disk chippers are machines having a steel disk attached at right angles to a shaft. A number of knives usually varying from 4 to 12 are attached radially in slots that permit them to extend beyond the face of the disk. As the disk rotates, the attached knives pass a single bed plate or square-edged stationary knife. A spout to hold the wood during chipping extends from the stationary knife outward at an angle to the disk. Adjustments of the knives and spout angle determine the size, shape, and quality of chips produced.

A small mobile disk chipper manufactured and marketed in Massachusetts is shown in Fig. 1. A tree trimming company has mounted this same chipper on trucks. The truck motor is used to supply power to the chipper, which is mounted behind the cab. Chips are blown directly into the truck body behind the chipper, thus making a complete tree trimming disposal unit.

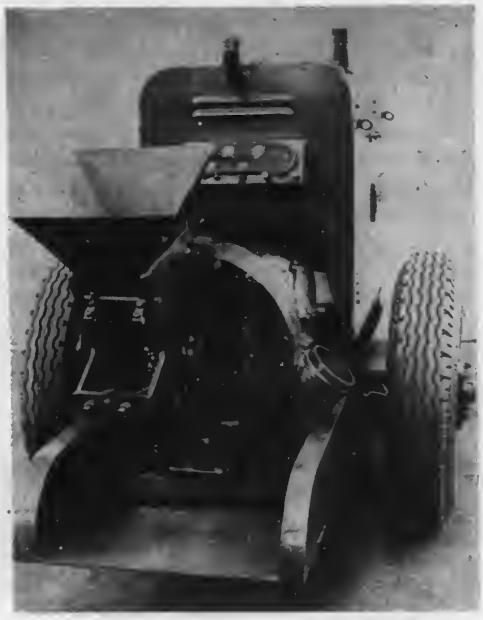

Fig. 1.—Small mobile disk chipper used for brush disposal.

A New York manufacturer designed and built a portable 10-knife disk chipper for the armed forces during the war. Although this unit has never been marketed commercially, the manufacturer is in a position to make additional units if industry wants them. It is a compact chipper and power unit with a base area approximately 4 feet by 5 feet using a hollow frame for the fuel tank. The spout is designed for round wood up to about 5 inches in diameter.

Neither of these machines was designed specifically for pulpwood, but they do produce

uniform chips from small round wood. There is, however, a portable chipper of this type for pulpwood up to 12 inches in diameter now being designed and built for trial by a Wisconsin manufacturer.

Cylinder Chippers

Two recently developed cylinder chippers resemble the action of planer or jointer heads. A steel cylinder on a shaft has recesses to hold knives parallel to the face of the cylinder as it rotates the knives past a single bed plate. Although available machines are designed for brush disposal, a Wisconsin manufacturer designed a larger stationary machine of this type designed to produce uniform pulp chips from slabs. Improving chip quality is justified because of the inherent advantage of the low, wide horizontal throat on this type of machine.

Depth of recess ahead of the knives and position of the bed plate determine the size and shape of wood fragments produced. Cutting done near the under side of the cylinder produces shavings. Cutting done higher up on the cylinder produces chips.

A mobile machine of the type manufactured in Massachusetts is shown in Fig. 2. A similar one for use on trailers is manufactured in Pennsylvania. These machines are used to dispose of brush along right-of-ways. The wide throat, which is especially designed for the purpose, permits easy passage of limby material. It is reported that round wood up to 6 inches in diameter or slabs can be chipped. As now used nonuniform chips are produced and efforts are being made to determine their usability as fuel.

Wood Hogs

The principal difference between wood hogs and other chipping machines is the number of bed plate knives used. These are usually two to four in number, spaced around one-fourth the circumference of the housing. Some machines have only one bed plate and produce uniform chips, but are, nevertheless, called hogs.

Fig. 2.—Mobile cylinder chipper with wide throat designed to dispose of brush along right-of-ways.

Fig. 3.—Mobile wood hog with a horizontal throat and power feed.

Two types of machines are made. One has a straight cylinder, while the other has a "V-type cylinder" that is between a cylinder and a pair of disks. The former may have knives extending the full width of the hog as on cylinder chippers or be studded with many short knives. On V-type hogs radial knives similar to those on disk chippers are used.

A mobile wood hog manufactured in Michigan is shown in Fig. 3. Both two- and four-wheeled models are made. These machines have a horizontal throat similar to cylinder chippers and the additional advantage of a power feed. A straight cylinder with 24 knives rotates past two bed plate knives.

Other portable wood hogs have been made by individuals from standard chipper equipment supplied by manufacturers. These machines are being used to dispose of orchard and shade tree trimmings as well as brush on land clearing operations. Some use is being made of the hogged wood to improve the soil but no attempts have been made to utilize it for industrial purposes. However, the same type of hog as used for brush disposal has been used to produce uniform chips by changing the knives and feed.

Changes are being made on a V-type hog in the Southeast in experiments to improve the quality of chips.

Hammer Mills and Shredders

Hammer mills and shredders are generally designed to produce a different type of material than that for which portable chippers are being considered. They do, however, produce wood fragments suitable for certain types of utilization. Portable and mobile units are used for other agricultural products, and should not be overlooked where special sized wood products are concerned, such as fines required for refining ores.

Factors Affecting Machine Selection

The power required is important in determining the maximum size of chipper that can be used as a mobile or portable unit. Machines that fragment wood by cutting and shearing require considerably less power than those that break or crush wood. Thus, disk chippers and V-type hogs require the least power. The power requirements range from about 7.5 to 11 horsepower to produce chips at a rate of one cord per hour.

Hogs and other machines that depend on both cutting and breaking require considerably more power. The amount depends upon the ratio of the two actions and the size of the material produced. In general, it requires considerably more power to produce fine wood fragments than coarse. Thus, the requirements may amount to as much as 40 horsepower per cord per hour.

The size of the throat opening obviously determines the size of rough wood that can be chipped by a machine. Hogs in general will accept larger wood than will disk chippers requiring the same horsepower. The ratio of horsepower to inch of opening varies with different machines from 1.7 to 15.0 horsepower per inch.

Insufficient data are available to compare throat openings and production rates with weight. However, it appears that throat opening in relation to machine weight is greater for hogs than for disk chippers. In other words, larger wood can be chipped in a hog than in a disk chipper of the same weight. On the other hand, production in cords per hour in relation to weight appears to be greater for disk chippers than for hogs.

In arriving at the above data and considering the suitability of machines for portable and mobile operations, it is found that V-type hogs are superior to other hogs. They also appear to have advantages over other wood fragmenting machines with the possible exception of cylinder-type chippers which cannot be included in this comparison because of lack of data.

Weight is an obvious consideration in mobile equipment, but production rate is equally important. Output of chips must be balanced with the transportation system and delivery of rough wood by the logging crews. Other factors that affect machine selection are: (1) state highway load and dimension restrictions, (2) transportation facilities used, (3) length of haul, (4) specification of chips to be produced, (5) ability of machine to withstand rough usage, (6) character and size of raw material to be chipped, (7) height of feed spout, and (8) equipment or method used in feeding rough wood.

Handling the Raw Material

Feeding wood to portable and mobile chippers is a major consideration and a phase that has caused failure in some early machines. With present disk chippers wood must be elevated to the spout. As the diameter of the wood increases so do the size of the chipper and the height of the spout. Thus, the heavier the wood, the higher it must be lifted. This condition imposes definite limitations on manually feeding wood to chippers.

Several solutions for this problem have been or can be used. One is to set the chipper alongside a bank and feed the wood in from above. Another is the use of a portable ramp up which men carry the wood. Mechanical feeding is possible by using mobile pulpwood conveyors of the type used for loading trucks in the Northeast.

Disk chippers used on mobile and semiportable operations have vertical spouts. However, others have spouts at small angles from the vertical, making them easier to feed. Improvements have been made in spout and knife designs, but the only radical change in overall design is a horizontal chipper, which has been developed in Canada. This chipper is more or less standard design except it has been rotated 90° from vertical. Developments that lower the spout height will increase the suitability of disk chippers for portable operations.

Cylinder chippers have a decided advantage in this respect since the wood is fed in nearly horizontally. Wood need not be up-ended to get it into the spout. This enables long or tree lengths to be chipped and thus reduces bucking and other logging costs. Also the throat design permits the passage of limb stubs and small branches. Increased size of these machines results in relatively minor increases in spout height.

Wood hogs are usually fed from a near vertical position, but the spout height in relation to the size of the machines varies within rather narrow limits. Horizontal power feeding is used in special applications, such as the portable brush hog. Other considerations are similar to those of the cylinder chippers.

Handling and Transporting Chips

Methods of loading and unloading transportation conveyances are different for chips than for rough wood. Blowers and trough conveyors are the most commonly used loading equipment. Unloading is usually done by the use of scoop shovels or dumping mechanisms, although suction equipment is sometimes used. A special type of truck with a central conveyor powered by the truck motor through a power takeoff is also available.

The space required for a given weight of chips is greater than for the same weight of rough wood. Variations occur depending upon species of wood, moisture content, size, and shape of chips, and other factors. Woods of various species received and chipped at the Forest Products Laboratory have averaged 243 cubic feet of green chips per cord of wood with variations from 210 to 291 cubic feet. Shaking and other actions, however, cause chips to slip and adjust themselves so that they occupy somewhat less space. Therefore, the average figure of 243 can be considered conservative.

Using this average figure as a basis, chip transportation by truck can be compared to pulpwood hauling. Commonly used pulpwood trucks haul 3 cords of wood. To haul the same weight or volume of wood in the form of chips requires a truck body with a capacity of 729 cubic feet, or 8 feet wide by 12 feet long, and about 7½ feet high. This size of truck body is not uncommon for hauling other products and are being used to haul chips and shavings in the Southeast. Similar trucks, especially selected for this purpose, are used to haul hogged wood on the West Coast.

Like computations can be made for other truck sizes. In general, properly selected trucks or truck and trailer units can be loaded to capacity with chips by using bodies higher than those to which loggers are at present accustomed.

Though the shipper cannot alter the size of railroad cars as easily as he can truck bodies, nor does he have so wide a selection of equipment, nevertheless chips are being transported by rail. Weight capacity per square foot of floor space is much greater for railroad cars than for trucks, and there is also a minimum load requirement that may in some cases be difficult to meet. For example, a box car with a capacity of 3,376 cubic feet has a load limit of 100,000 pounds or 50 tons. It will hold chips produced from approximately 13½ cords of wood. The weight of this volume of chips from the heaviest woods is considerably below the maximum, and for light-weight or dry wood even below the minimum requirements.

In comparison with pulpwood operations, it is found that approximately 18 to 20 cords are loaded in box cars. With heavy species it is possible to load to maximum weight limits and only in exceptional cases drop below the minimum requirements.

Gondolas and hopper-type railroad cars are more frequently used for chips. They are easy to load and often have trap doors in the bottom that facilitate unloading into mechanical conveyors. One model used for chips has a capacity of 2,547 cubic feet, or the equivalent of chips from about 10.5 cords of wood. By heaping the chips, however, about three more cords are added. On an operation chipping green, heavy hardwood slabs an average of 60,000 pounds of chips were being loaded into cars of this type. Another operation reported an average of 50,000 pounds where some softwood chips were included.

Careful analysis and proper selection of transportation facilities are important in reducing handling problems and costs.

Production Costs

Costs that can be profitably incurred on portable chipping operations vary considerably with the objective. In this respect brush disposal operations present the most opportunities for savings and the fewest problems to overcome. Production of high quality chips, on the other hand, presents the most problems and a narrower margin for profitable operation.

The available cost data on mobile and portable chipping operations are extremely limited. Costs, however, on one brush disposal opera-

tion using a portable hog and a two-man crew were as follows: Depreciation $125.45 per year; gasoline 1¼ gallons per hour; oil, grease, and maintenance 5 cents per hour.

Cost data on semiportable operations are comparable to mobile and portable operations. A very good analysis of these costs has been compiled by James T. Morgan of the Central States Forest Experiment Station, Columbus, Ohio, and published in a bulletin entitled "The Production of Wood Chips for Coarse Fiber in the Central States Region." These data indicate that on operations where stacked cordwood is moved from the storage yard to the chipper and then chipped and conveyed into railroad cars, the cost is $2.00 to $3.00 or more per cord or $1.00 to $1.50 per ton. In the same area on similar operations it requires two man-hours to load a cord of wood into a railroad car from a stock piles. On contracts the work is done for $2.50 to $2.80 per cord. Under these conditions the cost of producing chips is comparable to the cost of hand-loading cordwood.

The rate of producing chips for truck haul must equal or exceed the rate of hand-loading wood where storage bins are not used. For example, in the Central States it requires one man-hour to load a cord of wood. Thus, with the common three-man crew a truck is idle one hour while loading three cords of wood. Under these conditions a portable chipper must handle at least three cords, or six tons per hour, to deliver the same amount of wood. Similar comparisons can be made to determine the chipper capacity required to compete with other wood handling methods in any given area. In any analysis, however, it will be found that the cost of chipper operation is low in comparison to the cost of labor employed in handling wood.

On any operation the weight that must be handled by man is a limiting factor. Therefore, low feed spouts, mechanical handling, and chipping long lengths at rates balanced with transportation and other phases contribute materially to savings on portable chipping operations.

Desirable Improvement of Present Machines and Additional Information Needed

Wood harvesting operations using portable and mobile chippers are still in the developmental stage. The principal factors retarding expanded use has been the limited selection of machines and transportation equipment specifically designed for the job. Other factors have included inadequate planning, supervision, and coordination with cutting and skidding operations. Lack of equipment to remove or reduce the percentage of bark and manufacturing processes that use bark have also contributed to unsuccessful attempts.

Mobile chipping machines specifically designed for brush disposal are in successful

TABLE 1.—SUMMARY OF VARIOUS KINDS OF WOOD FRAGMENTS, AND THEIR USES, AND SPECIFICATIONS

Product	Use	How produced	Specifications
Chips	Pulp and paper industry	Wood is severed across its fibers and split along the grain at 0.5 to 1-inch controlled intervals along the grain to produce chips of uniform size.	Exacting. Chips must be of uniform size within narrow limits. Crushing of wood fibers is undesirable. Some bark is permissible in certain processes; others require bark-free chips.
Chips	Wood hydrolysis	---do---	Should pack well in digester. Some processes can utilize bark; others tolerate percentages slightly in excess of that normally found in round wood.
Chips	Ore refining; manufacturing steel	---do---	Size and form requirements vary. In one case chips or fragments as large as possible are used with or without bark in the carbonizing process; in another, small chips more nearly resembling sawdust are required.
Chips	Gas filtering and refining	---do---	To be chemically treated. Should be relatively long and thin, somewhat between chips and shavings. Some bark permissible. Should not pack tightly.
Hogged wood	Fuel	Random fragmentation by severing or breaking wood along or across the grain or at any intermediate angle to produce non-uniform chips. Is a product of sawmill and wood-fuel industries.	Fragments of varying sizes and shapes. Best mixed with sawdust for use in some burners.
Hogged wood	Wood hydrolysis Fuel, fiber, chemical, and special.	---do---	Same as for chips.

operation. Semiportable chipping plants are producing chips for utilization and shipping them long distances to processing plants.

Information gained from these operations indicates desirable improvements in chipper design and other factors that must be considered on mobile and portable operations. They also indicate the feasibility of operations and approaches to future improvements.

In order to gain these advantages, additional improvement in the machines themselves, research to utilize the material they produce, and determination of economic limitations are needed.

Two lines of advancement in machine development seem apparent. The first is to improve brush disposal machines so that chip quality can be adjusted to meet utilization requirements and increase the size of machines so that larger sizes of rough wood can be chipped. The second is to develop machines specifically designed to produce uniform chips from wood and meet the other requirements of portable and mobile operations.

Research is needed to determine the pulping characteristics, limitations, and necessary refinement of chips and hogged wood now produced by brush disposal machines from various sizes and species of wood. Similar efforts are needed for other processes, such as chemical conversion, or even for development of new processes to utilize this material.

Among refinements that are desirable or necessary is the reduction of bark content in chips. Several methods are being experimented with to reduce the bark content after chipping. The extent of these efforts and the factors involved should be determined. Then, if necessary, the work should be expanded.

There are limitations in diameter and length of rough wood that can be economically chipped for further processing. Beyond these limits chipping may be desirable and in some cases justified to utilize chips for improving the soil or the conditions of the forest floor. Such economic limitations need to be determined for chipping raw wood with portable and mobile chippers.

Discussion

Charles S. Walters (Illinois Agricultural Experiment Station): The estimate of $5,000 (given by the preceding speaker) is about half of what a portable chipper suitable for the Midwest would probably cost. The chipper itself would cost about $2,000, a diesel engine would cost about $4,000, and the frame, profit, and assembly costs would run the total cost considerably above $5,000.

We have about four or five plants in Illinois converting cordwood purchased locally into fiber for roofing felt, and portable chippers have been discussed many times. The term "portable" can include a wide range of machines: One can be portable if it is hauled on the bed of a 1½-ton truck for woods operations; another if it is hauled on a flat car which is moved from one concentration yard to another. A woods chipper in Illinois must be designed so that it can be moved in bottomland timber which often grows in rather wet sites.

Officials of the Ruberoid, Barretts, Johns–Mansville, and Certain-teed companies tell me that a 100-HP engine is too small for the chippers they use—which have a 12- to 15-inch throat. A 150- to 200-HP unit is about the minimum size that will do a satisfactory chipping job. If the engine is too small, the hardwood sticks will slow the engine down to the point where the chips become too thick to process satisfactorily. An engine of this size weighs a considerable amount and is expensive.

Converting hardwood slash into felt fiber is good utilization practice, but I believe Jim Morgan of the Central States Forest Experiment Station found that it is not currently economical.

Mr. Fobes: Comparison of chipper costs given by Dr. Walters and the previous speaker is difficult because each probably has in mind a different type of chipper. In either case the chipper cost is not so important as the cost of labor and transportation of chips compared with similar costs of handling cordwood.

As pointed out by Dr. Walters, the term portable is confusing, and for that reason an attempt has been made in this paper to differentiate between mobile, portable, and semiportable chippers. Mobile or portable chippers are the most desired for woods operations, although the majority of those in use are semiportable or fixed.

There are a number of good references dealing with power requirements of chippers.

There is, however, some variation due to auxiliary flywheels, flywheel effect of the chipper disk, and other design features. A good reference on this subject is "The Wood Chipper" by H. W. Rogers, published in Paper Industry and Paper World, September and October 1948.

Mr. Walters: What is the average diameter of the material being considered as suitable for producing chips in a portable chipper? For example, in some areas perhaps a chipper with a 6-inch throat is all that is required. In the Central hardwoods a 12- to 15-inch throat is needed.

Mr. Fobes: Not over 12 inches in the East.

Woodrow W. King (Texas A & M College): I am currently engaged in conducting a survey of mill waste in Texas. One of the objectives of the survey is an attempt to determine the amount of "chippable waste" available through the waste components of slabs, edgings, and trim. What information is available on the minimum size of material that can be used in portable chippers?

Mr. Fobes: The minimum size of material that can be chipped in portable chippers is not generally considered an important factor with slabs and edgings. The length of the material is the only important dimension, since it must exceed the width of the throat so that the material will not turn crosswise. Slabs and edgings generally proceed endwise through chippers producing uniform chips, but short pieces that can turn sideways produce splinters.

A. F. Wardwell (Carthage Machine Company): Insofar as we know, the first portable chipper was built by the Carthage Machine Company in 1939 for the Hummel–Ross Fibre Company, Hopewell, Va. It was essentially a standard machine which Mr. Fred Hummel mounted on a four wheel chassis with a Diesel engine. The unit was towed into the woods by a tractor which was periodically disconnected and used to drag wood to the chipper. When a radius of about 300 yards was covered it was moved to a new location. Chips were blown into a high-sided trailer or truck and hauled direct to a paper mill. The purpose of the operation was to make use of limbs and tops abandoned in pulpwood cutting and thus to obtain a cheap source of fibre. Chips were delivered to the mill some 20 to 25 percent cheaper than they could be produced then by conventional means. The unit was disassembled when the war started and has not been used by the new mill ownership.

One small chipper was built by the Carthage Machine Company during the war for the Corps of Engineers, U. S. Army. The plan was to fly the chipper to a new airstrip and produce chips on the site for camouflage purposes. The chips were to be painted and spread over the air field since it was known that visibility of air fields from the air depended not only on color but texture. The venture was reported as successful, but air supremacy precluded going into it on a large scale.

At the present time there is no truly portable chipper we know of that is satisfactory for producing good paper chips. There are a few excellent machines on the market for brush disposal. (Carthage Machine Company is developing a new portable chipper but does not now consider its earlier models sufficiently portable or light in weight to meet the requirements that are developing).

Mr. Fobes: The chipper described by you is the one referred to in my paper as being used in the Southeast about 1940. The reasons for its discontinuance involve too many factors to be adequately discussed at this time. Briefly, however, the more important factors involved wood handling and bark. I might add that chips from the chipper were blown against a screen that passed the fines, thus reducing the bark content.

Those persons I have talked to who were connected with the operation generally agreed that continuation was justified with modified wood-handling methods. Due to the radical change in economic conditions the cost data obtained at that time will not be applicable now. The operation did, however, prove that mobile chippers are mechanically feasible, and, under certain conditions, economically justified.

The portable chipper built for the Army was excellently designed. It was later purchased from war surplus by an industrial firm that operated it as a supplementary stationary unit. At the time of my investigation there were no available operating data applicable to portable operations.

FOREST PRODUCTS RESEARCH SOCIETY

Wood Fibers From Veneer Waste

Armin Elmendorf

President Elmendorf Research, Inc., Chicago, Illinois

A machine for producing strand-like fibers out of veneer waste is described. The fibers are cut at the rate of about 1 ton per hour. They can be felted by mechanical means and lend themselves to the manufacture of highly fire-resistant wall boards whose manufacturing cost will be far below that of plywood. Such boards in the ½-inch thickness are much stronger and stiffer than insulation boards of the same thickness.

PRACTICALLY all persons visiting plywood factories for the first time are impressed with the vast amount of veneer that falls into the waste conveyor and is carried from there to the power house to be used as fuel.

When used as fuel, veneer waste is worth only about $4.00 to $6.00 per ton, dry basis, depending upon the current value of competitive fuels, such as oil or coal. Roughly speaking, if coal costs $12.00 per ton, wood waste is worth about $6.00 per ton, as the fuel value of wood is about one-half of that of coal. The problem in utilizing veneer waste is, therefore, to give it a value exceeding $6.00 per ton. It should be borne in mind, of course, that in some localities wood waste is worth substantially less than $6.00 per ton; whereas in others, as for example those near a paper mill, veneer waste that is free of bark may command double this price.

Possibly the most unique property of wood is its high tensile strength parallel to the grain per unit of weight. It has been frequently pointed out that in this respect some woods are superior to mild steel. If wood is converted into long strands or fibers, its high tensile strength and stiffness can be used, but it is imperative that such fibers have ample length so that they can be held adequately with binders. This means, furthermore, that the fibers or strands must have a small cross section, for otherwise the resistance to rupture will exceed the bonding strength with which the fiber is held in place.

A balance between strength of bond and tensile strength is highly desirable. In veneer waste we have a uniquely useful raw material in that one dimension of the desired strands has been established by the act of cutting the veneer. By cutting the edge of veneer in a manner resembling that of planing the edge of a board we obtain strands or fibers whose width is the thickness of the veneer, and whose other dimensions, namely thickness and length can be controlled. The thickness, as previously stated, should be as small as is mechanically feasible in order that the tensile strength of the resultant strand may not be greater than the strength of the bond holding it in place. Tests made by Elmendorf Research, Inc. have shown that strands of this kind can be economically cut if their thickness ranges from about 0.010 to 0.015 inches.

The optimum length of the strand is determined by two considerations. As previously stated, it must be adequate to provide sufficient length for bonding purposes, but on the other hand its length must not be so excessive that it introduces mechanical difficulties in the formation of the desired end product. We have found that new types of wall board can be made of the veneer waste fibers. It is highly desirable that all hand labor be eliminated in the manufacture of such boards. In order to be able to felt the fibers into a uniform board-like product by mechanical means, we have found it necessary to limit the length to about 6 or 8 inches. Fibers of conventional excelsior length tend to snarl and lump and, therefore, do not lend themselves to mechanical felting. For this purpose most of the fibers must be thrown and deposited as individual strands. On the other hand, unless the strands are at least 1 to 2 inches long they do not, as a rule, provide adequate bonding strength.

To summarize: For the best utilization of veneer waste in the manufacture of new wall boards and building slabs, it appears that the fibers or strands into which the veneer is converted should have a width equal to the thickness of the veneer, a strand thickness of from

0.010 to 0.015 inches and a strand length ranging from 1 to 8 inches.

Fiber Cutting Machine

Considerable work has been done in the laboratory of Elmendorf Research, Inc., over a period of years in the development of a machine that would produce fibers of the type and size mentioned. A great deal of our research work has also gone into the utilization of such fibers for the production of useful board-like products. Following the successful completion of a laboratory machine for reducing veneer waste to fibers of the type described, a full-sized machine for cutting fibers in commercial quantities was built. The latter machine has now been completed and tested. It, too, produces the desired fibers. This machine is illustrated in Fig. 1.

It may be seen from the illustration that veneer waste of random width, shape and thickness, previously cut to a maximum length of 1 foot is placed upon a conveyor belt that carries it forward into the clamping mechanism, which in turn feeds it continuously against the face of the cutting disc. All types of green veneer waste commonly observed in waste conveyors can be used, as for example, fish tails, narrow strips, split veneers, and knotty material. In its progress to the cutting disc, the bed of randomly placed veneers, which is about 4 inches thick, is cut down the middle with a circular saw, thereby producing two separate continuous beds each 4 inches thick and 6 inches wide.

It may be noted that the flat side of the strands cut is edge-grained, and that when such strands are felted the broad surface of most strands lies parallel to the faces of the resultant board. The advantages inherent in edge-grained wood are thereby incorporated in the board. The dimensional changes of wood in

Fig. 1.—Machine designed by Elmendorf Research, Inc. for converting veneer waste into strand-like fibers. (Courtesy of the Harbor Plywood Corporation.)

the radial direction due to moisture changes are roughly only about one-half of those in the tangential direction. As minimum dimensional change is one of the most important physical properties of all wall boards, it is highly desirable that the strands be so cut and placed that they show edge-grain when positioned in the final board. This is the result obtained with the fibers produced by the fiber cutting machine we have designed and built.

The machine illustrated cuts 1/8-inch and 1/10-inch Douglas fir veneer waste into fibers at the rate of about one ton per hour. In commercial use these fibers will be drawn away from the fiber cutting machine by air suction to be transferred either to a dryer, or to be carried in the green state to mixing machinery for coating with appropriate binders.

Veneer Fiber Boards

Various binders can be used for binding together the fibers produced with the machine described, but of these, two types are of major importance. One type of binder producing a highly useful board is the synthetic resin binder, such as, urea and phenol formaldehyde resins. On account of their cost, such resins must be used in the minimum amount consistent with obtaining the desired physical properties in the end product. If urea resin is used, satisfactory bonds can be obtained with a resin content ranging from 10 to 20 percent. The fibers freshly coated can be bonded in a hot-plate press without surface ventilation, if the pressure used does not shut off internal ventilation within the board. The resultant board must be somewhat porous. Boards having a density of from 0.60 to 0.80 made in this manner have a modulus of rupture ranging from 3,000 to 4,000 p.s.i. Such boards need not be subsequently finished in any manner as the fibers have a thin coat of resin, and the natural color of the wood is substantially maintained. They may, of course, be finished by painting or varnishing if desired.

Wall boards 4 by 8 feet in size and 1/4 inch thick have now been produced with the veneer waste fibers. The texture of the board surface is attractive and is generally regarded as having excellent decorative value.

When phenolic resins are used, superior weather resistance is provided, but the board produced is darker and, therefore, not so satisfactory for wall board use in house interiors.

Fig. 2 shows various types of wall board made of veneer waste fibers and also a small pile of veneer fibers produced by the fiber cutting machine described. Panel No. 3 in this figure shows a 1/4-inch board made with urea binder.

Sample No. 5 in the illustration is cut from a plaster base made of the veneer waste fibers bonded together with portland cement to which certain chemicals have been added. This plaster base is 3/8 inch thick, and 16 by 48 inches in size. Only about one-third of a pound of fibers are required per square foot of board. Being porous, this plaster base provides a superior surface for the keying of plaster. Similar products have been used in Europe for several years on a very large scale. The European products are, however, made of excelsior which is a much more expensive fiber; furthermore the formation of the board abroad is a hand operation, whereas the veneer fibers produced as described can be mechanically felted.

Observations made in several plywood factories indicate that the weight of the veneer waste may be about one-third the weight of the plywood manufactured. If all the veneer waste available in an average Douglas fir plywood plant could be converted into board for use as a plaster base, the footage of the board produced would equal approximately the footage of the plywood produced by the factor, as only about a third of a pound of fibers is required per square foot.

A third board product that can be made using inorganic binders is shown at No. 2 and No. 4 of Fig. 2. Specimen No. 2 has been given a finer surface texture by the use of a surface layer of fine fibers. Specimen No. 4 shows the texture obtained with fibers cut from 1/8-inch Douglas fir veneer waste. Both boards are 1/2 inch thick. They are highly fire-resistant, and they are a great deal stronger and stiffer than conventional 1/2-inch insulation boards. These boards can be made in wall board sizes in a continuous operation by mechanical means, and practically all of the hand labor involved in the manufacture of plywood, for example, can be eliminated. The estimated cost of materials of these boards, in the 1/2 inch thickness

is less than 1 cent per square foot if we assume the veneer waste to be worth $6.00 per ton; and the estimated total manufacturing cost, when produced on an efficient commercial scale, will probably not exceed 1½ cents per square foot. This estimated cost covers all materials, labor, and overhead.

It may be seen, therefore, that new types of highly useful building boards can be made out of veneer waste, and that such boards have some desirable properties that plywood does not have as, for example, fire-resistance.

Moreover, when inorganic binders are used, such boards are not only fire-resistant, but if their porosity is maintained in manufacture, they also absorb sound and are useful for sound quieting purposes. They may be used as a base for plaster or they may be painted or left in their natural white color. Their manufacturing cost will be far below that of plywood, and furthermore the total footage that can apparently be produced out of the veneer waste of the plywood industry may approach the total footage of plywood produced by the industry.

Discussion

Richard L. Burkhart (National Veneer and Lumber Co.): Can hardwood waste be used satisfactorily?

Mr. Elmendorf: Hardwood veneers can be cut successfully on the Elmendorf machine. Some hardwoods (and redwood) have solubles that inhibit setting of Portland cement. These

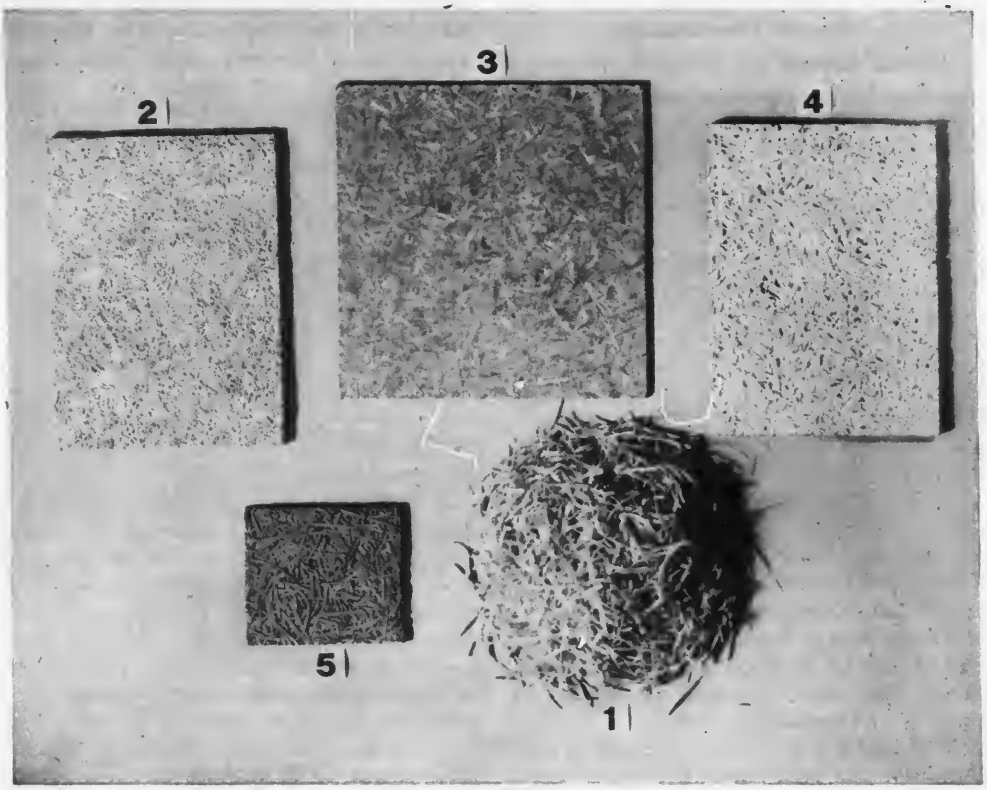

Fig. 2.—Various types of wall board made of veneer waste fibers. (1) Strand-like fibers produced from waste veneer by the Elmendorf fiber cutting machine. (2) A fire-resistant wall board made of veneer waste fibers and having a finer fiber in the face. (3) A ¼-inch board made of veneer waste fibers bonded with urea resin. (4) A fire-resistant wall board ½ inch thick made of veneer waste fibers, bonded with an inorganic binder. (5) Sample cut from a plaster base ⅜ inch thick, size 16 by 48 inches, made of veneer waste fibers, bonded with portland cement.

can generally be dissolved out with mild cook, which adds somewhat to the cost. Oaks cannot be used.

Mr. Burkhart: Can dry waste be used satisfactorily in the process?

Mr. Elmendorf: Material should be cut green, but for some processes the fibers must be dried before the binders are added.

Burdett Green (American Walnut Manufacturers Association): Does 15 to 20 tons per day of available waste require a reasonable investment?

Mr. Elmendorf: It requires a hot plate press for urea and phenolic bonded boards. Portland cement board requires a special felting machine, costing not over $50,000.

C. K. Textor (The Bauer Bros. Co.): What is the nature of the felting machine?

Mr. Elmendorf: I prefer to elaborate in a separate paper. Felting is fully mechanical.

E. George Stern (Virginia Polytechnic Institute): Considerable amounts of hogged wood waste and sawdust are available for molding of wall and core boards. By adding adequate amounts of synthetic binders, satisfactory boards have been produced with these wastes. The suggested use of strand-like fibers from veneer waste may result in a certain decrease in required amount of binder, in comparison with that required according to present molding practice, because of the length of the strands and the possibility of properly felting them into board products. On the other hand, the cost of manufacture of strand-like fibers and their felting may compensate for the decrease in cost of required binder. A comparison of production cost data for boards having similar physical and mechanical properties could be helpful in deciding which raw materials can produce the most economical product.

Relationship of Small Permanent-Type Sawmills to Better Forest Utilization in the Northeast

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The diminishing quantity as well as quality of saw timber in the Northeast and the gradual acceptance of better forest management practices has made the small permanent-type sawmill an ideal means for fully utilizing the available timber resources of this region. Such important factors as mill location, labor, power, remanufacturing facilities and general efficient operation are briefly evaluated in their relationship to overall forest utilization.

Historical Background

TO GAIN a better insight into the present logging and lumbering trends in the Northeast, it is best to review the developments in this industry since its conception in colonial times. When the first settlers set foot on the cold, rugged New England shores they were confronted with the immediate problem of constructing shelter to protect them from the approaching winter as well as the supposedly savage Indians. They turned, naturally, to the surrounding forests for their building material and with broad axe and whipsaw fashioned their first simple dwellings. Eventually as the colonies enlarged greater demands were made on the native forests for wood products other than that merely for home construction. Ship building and a budding furniture industry called for ever increasing supplies of lumber and this great demand inevitably led to the construction of a sawmill.

The exact date and birth place of the first sawmill erected in America is rather uncertain but it is generally believed to have been about 1631 and the place, South Berwick, Maine.[1] This mill, as well as others that followed it, was located on a river which supplied both the necessary power and transportation. Here logs were sawn into lumber by means of single bladed up-and-down saws, really a mechanical adaptation of the old hand whipsaw. Timber was plentiful and large so that getting the logs to the mill was relatively simplified by cutting them along the river above the mill and floating them down to the mill pond. The river also served as a means of distributing the sawn product to settlements farther downstream and along the coast.

Gradually as the demand for lumber increased, in the face of an ever diminishing supply of logs upstream from the mill, the operator was forced to either seek other means of log transportation or to move his mill to another unexploited stream. Moving the mill, however, entailed the costly procedure of constructing a new power dam and that factor alone placed definite limitation on the mobility of these early mills.

The invention of the steam engine and circular mill during the 19th century overcame many of these limitations and was instrumental in introducing the portable sawmill era to the American lumber industry. Later the development of the internal combustion engine gave even greater mobility to the portable mill. Expanding markets for such specialized items as railroad ties found the portable mill admirably suited for that type of production. Such, then, was the general lumbering picture in the Northeast, particularly in southern New England, until very recently.

The Small Permanent-Type Sawmill

Today, however, we are witnessing another trend in the sawmill industry; that toward the small permanent-type mill. The reasons for this trend are fairly obvious after considering the other great advances in industrial mechanization during the recent years. It was only imperative that the lumber industry should follow suit.

Although the portable mill has been found highly adaptable to conditions prevailing throughout the Northeast it has, at present,

[1] Holbrook, Stewart: *Tall Timber*. 1941.

several definite limitations in respect to a rising demand for more complete utilization of the few remaining stands of merchantable timber. Today the problem is not only to produce a necessary quantity of lumber for profitable operation but to produce as well a quality of lumber which can stand on its own in competition with that from other regions, notably the South and West. In order to realize this aim the progressive Northeastern mill man has found the solution in the small permanent mill. While referring to the permanent-type mill emphasis is placed on the small mill rather than the large mill, in that it is our opinion that the size of the existing stands and the density of merchantable timber in these stands do not economically warrant the establishment of any large mills in the Northeast.

Some Features of the Permanent Mill

A small permanent mill differs from a portable mill mainly in that it is set up with the intent purpose of producing lumber from timber brought to the mill rather than producing lumber by taking the mill to the timber. A permanent mill can consist of either a circular or small band mill located advantageously on a good highway or railroad or better yet on both. Usually a sufficiently large and fairly level site is selected to permit for ample log storage, stacking of lumber and possible future expansion. (Fig. 1) Also since the mill is located either in town or at the edge of town, it offers the available labor supply not only more satisfactory working conditions but is itself assured of obtaining a better and more reliable type of laborer.

The erection of a small permanent mill with its accompanying greater expenditure of funds generally warrants an outright purchase of a mill site or at least a long term lease on such a site. Investment of capital in real estate and buildings promotes confidence in the integrity of the operator which later manifests itself in better business relations between operator and timber owner as well as between operator and consumer. Many stumpage owners have, either from past unsavory experience or hearsay, come to distrust the generally poorly financed portable mill operator. The permanent mill does

Fig. 1.—Layout of typical small permanent-type sawmill planned for straight-line production from log deck to finishing mill.

much to allay this distrust and in turn produces the proper atmosphere of mutual good faith so essential in the establishment of an enterprise basing its continued existence on a sustained supply of raw material.

A permanent mill, because of its selected location, is also in a better position to take advantage of various power sources, especially electricity where available. The efficiency of industrial electric power has long been recognized and its convenience, of course, is beyond dispute. Small electric motors running clippers, resaws, edgers and planers greatly increase the quality of lumber produced by the small mill. Remanufacturing of the lower grades of lumber also means greater possible utilization of the lower grade logs which are and always have been the problem child of the mill owner. A survey of several small permanent mills in our vicinity has revealed that a substantial part of their income is derived by cutting small dimension squares from slabs, edgings and low grade lumber. (Fig. 2)

Better mill layout is possible on a permanent site making for more efficient production. From log storage deck to carriage and thence through the mill one continuous straight line operation can be planned. In our own mill the log moves from dead storage to mill deck by means of a small crane. (Fig. 3) From there it is rolled onto the carriage of our electrically powered circular mill. As the sawn product leaves the head rig it is shunted through edger and trim saws and thence on a live conveyor out to the sorting shed. The recent addition of a modern cross circulation dry kiln and a planing mill (Fig. 4) has given us additional means for further utilization. All operations are planned in such a manner as to reduce unnecessary manual handling; an essential in these times of high labor costs.

Fig. 2.—Hardwood squares, a profitable by-product of a well arranged mill.

Fig. 3.—A small crane makes an excellent log and lumber handling device in the mill yard.

Fig. 4.—A small dry kiln and planing mill increase the quality of lumber produced.

Conclusion

The small permanent type sawmill has given the mill operator in the Northeast a most efficient means for fully utilizing the limited supply of remaining timber. Advantageous location of mill site in regards to markets, transportation facilities, power and labor supply all contribute to greater utilization of the available stumpage. A permanent year round demand for logs by the mill encourages better logging and forest management practices on the part of timber owners in the immediate working circle. Integrated utilization is not only possible but also quite profitable in that all species and all lumber grades can be marketed in one form or another. General efficiency is also greater and unit operating costs consequently lower.

Discussion

Eugene W. Fobes (Forest Products Laboratory): Portable mills reduce logging costs but do not provide facilities for further manufacture. Small permanent mills will probably need to be supplemented by portable mills. A portable mill can produce material of equal quality to that of a permanent mill.

Mr. Tolle: When this question is viewed strictly from a cost basis we can concede that the difference between getting the logs into a portable mill as compared with getting them into a permanent mill is chiefly the cost of trucking. By using specialized logging trucks and loading methods this cost factor can be kept at a minimum and consequently is generally exceeded by the additional revenue obtained from a more integrated utilization program at the permanent mill.

It is quite true that some portable mills produce excellent lumber, but considering averages the quality in portable mills does not match that in permanent mills. The market bears that out.

Fred C. Simmons (Northeastern Forest Experiment Station): It has become almost trite to say "the motor truck has moved the sawmill out of woods." That is true to a considerable extent. Mr. Tolle has pointed out the reasons and advantages very well. There are some disadvantages. Perhaps the most important is that permanent mill settings discourage the use of small and low-grade logs. Such logs may weigh up to twice as much per M (of material recovered) as higher grade material. In many cases perhaps we don't want to saw such low-grade material into lumber. But as high-grade material, particularly of hardwoods, becomes scarcer we are going to have to obtain many of our hardwood products, such as furniture parts, from low-grade logs. The new mobile mills are one promising attempt at a solution particularly well adapted to cut high-grade logs from farm woodlots.

Mr. Tolle: I agree with Mr. Simmons that the scarcity of high-grade logs will eventually compel the operator to obtain his hardwood products, such as furniture parts, from lower grade logs, but when this time arrives I sincerely believe that the permanent mill with its better remanufacturing facilities, more diversified markets and greater efficiency will still be able to do a better job at "complete utilization" than the more mobile portable mill.

Pulpwood Handling in the Lake States

O. O. Koski

Forest Engineer, Minnesota and Ontario Paper Company, International Falls, Minnesota

Pulpwood handling in the Lake States has become a ist operation in the bu'k movement of raw material from the forests to the numerous convers on plants. Thi. paper covers the various steps necessary and equipment used in pulpwood handling, and gives a general idea of the methods and the equipment employed to annually supply the Lake States pulp, paper and paperboard mills with their all important raw material.

Introduction

TO ILLUSTRATE the relative size of the industry which is dependent on pulpwood being delivered, Lockwood's Directory lists 112 pulp, paper and paperboard mills in the Lake States of which about 47 percent are in Wisconsin, 43 percent in Michigan, and 10 percent in Minnesota. The 1947 Annual Report of the Lake States Forest Experiment Station states that the average drain of rough pulpwood for the ten year period 1935–44 was 2,349,000. cords annually. At a conservative figure of 20 dollars a cord, the above volume of raw material represents an annual outlay of approximately 47 million dollars. Pulpwood handling is big business.

The subject of pulpwood handling in the following discussion has been divided into its natural steps of falling, skidding, bucking, loading and hauling.

Falling

The species commonly used for pulpwood in the Lake States are: Black spruce *(Picea mariana)*, white spruce *(Picea canadensis)*, balsam fir *(Abies balsamea)*, jack pine *(Pinus banksiana)*, aspen *(Populus tremuloides)*, tamarack *(Larix americana)* and hemlock *(Tsuga canadensis)*. Most of the pulpwood is still cut in the old conventional manner with axe and saw. Portable power saws, however, are being used more and more each season.

Pulpwood is cut by two basic methods—either in four-foot or eight-foot pieces or in tree lengths. Most of the annual harvest is cut in the shorter lengths for which payment to the cutter is made either on a piece-rate, so much per stick or stacked cord, or a straight hourly rate basis. With the exception of larger pieces, the cutting of shorter lengths involves not only falling and trimming; but includes bucking into the specified shorter lengths and piling along strip roads. A strip of timber sixty to one hundred feet in width and the length of a forty is assigned an individual cutter. A strip road, not exceeding ten feet in width, is cut down the middle of the strip along which the pulpwood cut in short lengths is piled according to species. This strip road, if the cutter is on a piece rate basis, must be made by the cutter at no additional compensation.

Cutting in tree lengths is a relatively new method. Some experimental cutting in this manner was tried in Michigan and Wisconsin, but from the latest reports operations have reverted to the old method of cutting in shorter lengths.

In Minnesota tree-length cutting has become quite popular and indications are that in the future an increasingly larger percentage of the total pulpwood production will be cut in this manner. Tree-length cutting makes the cutter's task much less ardous in that no lifting is necessary as the piling is eliminated.

In actual practice a cutter is assigned a strip as in the former method. He begins his falling operation at either end of the strip. All trees are fallen in a herringbone pattern, so that either the tops or butts of the trees are easily reached with a winch cable from the strip road. The cutter's duty is to fall the tree in the desired direction, limb and top the trunk. Payment to the cutter is on the basis of an established piece rate per tree length for various sizes or by the hour.

Skidding

Skidding is done in both summer and winter, but winter is the most favorable season. Short length pulpwood is skidded to the loading point or the stock pile landing on a

wooden two-runner sled called a dray. A dray to be pulled by a team of horses is made for a three-quarter to one cord capacity. Drays used for tractor-skidding are generally a little wider to accommodate pulpwood up to one and one-half cords. The procedure is simple. An empty dray is pulled down a strip road to a pile of pulpwood piled previously parallel to the strip road by the cutter. The pulpwood is hand loaded lengthwise by two men on the dray. The dray load of pulpwood is then transported either by horses or by tractor to the loading point or to the stock pile landing.

The alternate method used is tree length skidding. This is done either by means of horses or tractor. A single horse or a team is used depending on the size of the timber and the ruggedness of the terrain. For the hitch for a team a one-half inch logging chain and a hook is used. Horse skidding is generally believed to be the most economical for shorter skidding distances.

For longer skidding distances—600 feet or more—tractor skidding is more advantageous since more power is available and bigger loads can be handled. Tractor skidding can either be ground skidding or sulky skidding. Generally ground skidding with a tractor is done where short skidding distances are encountered. On longer distances a sulky is used. A sulky is a two-wheeled vehicle supporting an arch. At the top of the arch a sheave is so located that a cable from the winch drum of the tractor passes over and through the sheave. The sulky is attached to the tractor drawbar by means of a tongue extension from the arch. The sulky suspends one end of the tree length off the ground, preventing it from digging in when yarding. The use of a sulky insures clean, rock-free logs, reduces wear and tear on logging roads and steps up production.

Generally a hook is used at the end of the winch cable, commonly referred to as the main-line cable, so that a number of cable chokers can be attached making it possible to fasten onto a number of tree lengths at one time. Approximately a cord of pulpwood in tree length is considered a capacity load.

In actual practice the skidding crew for a skidding unit consists of the tractor operator and a choker setter. The choker setter's duty is to attach the choker cables to the tree lengths to make up a sulky load. He then pulls the main line cable of the tractor winch in position to enable him to attach the choker cables to the hook on the main line. The tractor operator winches in the tree lengths. Should this not be sufficient for a load the same procedure is gone through until enough tree lengths are dragged adjacent to the strip road to warrant a trip to the landing. The ends of the tree lengths are then lifted clear of the ground by means of the sulky and the winch cable. The load is skidded into a yarding point for subsequent handling (Fig. 1).

A tractor of from 25–35 drawbar horsepower is generally used for sulky skidding. A sulky capable of carrying the equivalent of a cord of wood in tree lengths is used with the tractor. Naturally the production of a skidding unit depends on the conditions of the forest stand, the distance to be skidded and the terrain. On most operations in the Lake States a skidding unit of this type would skid from 15–20 cords per working day. The tractor operator and the choker setter are paid by the hour.

Bucking

In logging by the conventional system the bucking of the tree into shorter lengths is, of course, done by the cutter immediately after falling the tree. This bucking is done under adverse conditions and in addition requires quite an expenditure of physical energy in that each stick must be carried a considerable distance to be piled adjacent to the strip road.

The elimination of much of the "bull work" is an important factor in the recent trend toward more tree-length logging. Tree lengths at landings are bucked up into shorter lengths in various manners. The common method used today is bucking on the ground with portable chain saws. As the tree length is skidded to the landing it is marked off into the desired shorter lengths and bucked by two men with a two-man power saw. On completing the bucking of a number of tree lengths, the same crew with the addition of a third man stock pile the shorter lengths in readiness for future loading. The above method is employed usually on the smaller operations on which a small area of timber is to be cut and a small crew employed.

On larger operations specially constructed slashers are used. The two common types are

Fig. 1.—Tractor and sulky with load.

the circular saw slasher and the chain saw slasher. The circular saw slashers vary from the crude homemade machine to a well designed factory-made machine. Most circular saw slashers also incorporate a conveyor truck loading attachment.

The power unit commonly used on a factory-made machine is a V-8 Ford 40 hp. motor. This motor drives a tree conveyor that places the tree length under the saw. It is actuated by the sawyer advancing a hand lever to bring the tree length up to the cut-off stop for each cut. A cable crosshaul, powered by the same motor, is controlled by a separate operator. The cross haul pulls tree lengths from the point of deposit by the skidder onto the tree conveyor. A 44-inch circular saw, its swing controlled hydraulically by the sawyer, does the cutting. A loading conveyor removes the pulpwood sticks as they are cut and transports the same to a truck placed in position. The extension apron of this conveyor is raised and lowered hydraulically to facilitate loading (Fig. 2).

In operation a five-man crew is needed for the slasher. Two men man the two cables on the cross-haul. Their duty consists of attaching the hooks at the ends of the cables to a tree length and detaching the same on the tree length being pulled onto the tree-conveyor. A third man operates the controls of the cross-haul winches. A sawyer operates the tree conveyor and the swinging saw. The fifth man assists the truck driver in properly placing the pulpwood sticks on the truck as the sticks fall from the loading conveyor. An average daily production of 60–70 cords can be cut and loaded on trucks with this type of a slasher-loader.

Only one chain saw slasher is in existence to the best of the writer's knowledge (Fig. 3). This machine has an overall length of 49 feet. It is about six feet high and six feet wide. It is powered by a diesel unit of 64 belt horsepower mounted on the framework. The operating control levers for the machine are located at one end of the machine for one man control.

Fig. 2.—Circular-saw slasher-loader.

The main features of the machine consist of chain saws, hydraulically operated lifting arms and a conveyor system.

The cutting components of the machine are seven individual standard Disston chain saws, 133 inches long, which are spaced on eight foot centers, enabling the machine to produce six pulpwood sticks from one log. Each saw has forced feed lubrication, powered from the main power unit shaft.

The lifting arms, fabricated of ½ inch steel plate welded to 3½ inch extra heavy pipe, are hydraulically operated. By means of a lever, the machine operator controls the movement of the lifting arms to engage each log. Upon being cut, the eight foot pulpwood is conveyed to the end of the machine where it is sorted, bunched and loaded by crane onto the waiting trucks.

This machine is very efficient in its cutting operation. The fact that varied species can be cut and sorted due to the ability of the take-away conveyor to travel in either direction greatly simplifies the logging of a mixed stand. However, since a crew of twelve men are required to operate the same, its use is limited to a large volume operation. Attempts have been made to diminish the size of the operating crew by further mechanization; but as yet, the solution has not been found.

Briefly, the operation of the chain-saw slasher is as follows: Skidding tractors equipped with sulkies deposit tree-lengths onto a skidway. Two men detach the chokers. Each tree-length is then rolled a short distance onto a set of horizontal rollers. Three men at this point line up one end of the tree length with an end saw to eliminate the necessity of a short butt cut. The tree-length is then rolled another foot so that the lowered lifting arms will cradle the tree-length on being raised. The tree-length then is forced into the speeding chain saws. The cut sticks fall into a V-shaped conveyor trough and thence are conveyed in one direction or the other. On the end of the machine to which the predominant species of the timber

Fig. 3.—Multiple-chain-saw slasher.

stand go, two men receive the sticks on an apron from the discharging conveyor. The sticks are shunted to one side or the other to be bunched by two additional men. The same procedure is gone through on the other end of the machine receiving the minor species except that here all functions are performed by two men. A crane on crawler tracks then shunts back and forth to either end of the machine to load the bunched wood with a bucket directly onto a waiting truck. The operator of the machine sits in a partially enclosed cab at one end of the machine in a position to allow him to see most of the crew members and the operating machine. Given sufficient tree lengths a slasher of this type can cut 120 cords of pulpwood per eight hours. In stand of timber considered only fair this machine has maintained an average production of 90 cords per day.

Loading

Loading of pulpwood in the Lake States is done by a number of means ranging from manual loading of trucks and railroad cars to the use of expensive cranes. Hand loading is still done by the smaller operators. The hand loading of railroad cars from trucks is aided somewhat by the use of loading platforms at railroad sidings.

A simple mechanical device which is quite widely used for the loading of trucks in the woods is the forest jammer. This jammer provides an effective means of transferring pulpwood from sleighs or drays to trucks and trailers. The jammer is basically composed of an upright wooden mast, a wooden swinging boom that rotates about the mast, a power unit that drives a winch drum, lifting cable, and sheaves at the base of the mast, at the base of the boom and at the extreme end of the boom. Stabilizing lines are attached to stumps for anchorage, passed through sheaves near the top of the mast, and terminate on small hand-operated winches permanently attached to the jammer base. The vertical axis of the mast is deflected from a true perpendicular by adjust-

ing the stabilizing lines. A slight angle from the perpendicular causes the boom to swing, by gravity action, in the direction of the tilt of the mast. Return is accomplished manually. In operation, the position of the mast is adjusted to use the gravity swing when a load is suspended from the hoist line. By spotting the truck under the low point in the boom arc, loads may be lifted and swung to that point. During the loading operation, the truck is moved forward or backward to spot the sling loads at the desired location on the pulpwood rack of the truck. A jammer of this type is capable of lifting loads of one cord. Its capacity in cords per day depends on the type of wood being handled and the skill of the operators. Generally an eight cord truck load can be formed in 20 minutes. A crew of four is required—the operator, two sling handlers and a top loader.

Among the commonly used factory built devices for the loading of pulpwood both in hot-logging operations and on loading trucks from stock piles are: the truck-mounted hydraulic crane, the tractor-mounted crane, and the wheel and the crawler type commercial cranes. The above types of loading equipment are all very mobile and thus lend themselves well to most loading situations. They can be used either with loading slings or pulpwood buckets depending on the conditions of the loading operation. All have the advantage of requiring a relatively small loading crew.

In upper Michigan a common type of equipment for loading railroad cars, either flat or gondola, is the home-made gantry crane. This is a stationary unit composed of a power unit (usually housed), an overhead frame work that traverses a truck road and the railroad tracks, a traveling carriage upon the overhead frame work and sheaves and cables connecting the hoist block with winch drums in the power unit house. A car pulling drum is also powered by the one power unit. Special trip slings are used to transfer the pulpwood load from the truck to the railroad car. As much as three cords have been handled at one lift with this type of loading device. If much wood is to be loaded, a good size railroad siding is necessary to store empty as well as loaded cars. A two-man crew can handle the loading operation, although if the wood is coming fast, a four-man crew would be the most efficient.

Hauling

In the Lake States, the hauling of pulpwood is done either by rail or by automotive truck. Rail hauls are confined generally to the longer hauls. Truck haul for distances up to 100 miles is the general practice.

In Minnesota trucks with semi-trailers are used quite extensively. Within the past few years the trend in trucking leaned toward heavier road equipment; however, the campaign of the State Highway Department on adherence to the axle weight limits during the winter season as well as during the summer have made trucking with heavier and safer equipment prohibitive.

Bob-tail trucks are used more in Michigan and Wisconsin; but with the increase in truck hauling distances trucks equipped with semi-trailers are becoming more popular.

Under the present highway restrictions in the Lake States a light weight truck with a light trailer dolly and pulpwood rack is the most practical for the hauling of pulpwood. A seven-cord load can generally be legally transported depending, of course, on the per-cord-weight of the pulpwood.

In closing it should be mentioned that in recent years the handling of pulpwood has been vastly improved by progress in mechanization. Due to the nature of the product and the conditions under which its handling must be done, progress is not as rapid as has been the case in other branches of the paper industry.

Discussion

Norman F. Smith (State of Michigan Department of Conservation): What is the proportion of pulpwood handled in tree lengths versus short lengths in the Lake States?

Mr. Koski: The proportion of pulpwood handled in tree length versus short lengths in the Lake States is very small. An attempt at stating a percentage would only be an unreliable guess.

L. W. Hooker (Michigan College of Mining and Technology): While Mr. Koski's statement that tree-length skidding in Michigan and Wisconsin is being abandoned in favor of the

older method of short-length cutting is undoubtedly true regarding the operator who produces only pulpwood, the reverse is true in the case of the operator who produces both sawlogs and pulpwood in the same operation. One logger has stated that his logging costs were reduced as much as 25 percent by the adoption of the tree-length method of skidding. This saving was made possible because of the following factors:

1. The skidding capacity of his tractor was more than doubled through the use of sulkies.
2. Main haul-road construction was reduced by 50 to 75 percent because longer skidding turns were possible. In many instances only two roads per section were needed.
3. By having all logs bucked on the landing, he realized a much greater percentage of high grade logs. Only one or two men had to be trained to buck for grade instead of each felling crew.
4. He felt that in most instances he could charge the entire skidding cost to his sawlogs and consider that the pulpwood and chemical wood had a free ride to the landing as an integral part of the log tree being skidded.

Perhaps the pendulum is swinging back, because under certain conditions, the tree-length method of skidding is being regarded with increasing favor in Michigan.

Mr. Koski: The writer is in agreement with Mr. Hooker's statements.

Frederick H. Vogel (Alabama Polytechnic Institute): During the past several months, we have felt that lowering pulpwood prices in the South have been causing a squeeze on the pulpwood operators. I am wondering if the same situation holds true in the Lake States, and if as a consequence, the operators are having to cut costs by every means at their disposal?

Mr. Koski: Yes, I believe, this trend of lowering pulpwood prices is also true of the Lake States necessitating a subsequent cost cutting by the producer.

Roy M. Carter (North Carolina State College): What is relative cost between tree-length handling and pulpwood lengths?

Mr. Koski: In small diameter stands of pulpwood cutting in pulpwood lengths is definitely cheaper. However, in large diameter stands allowing the pulpwood to remain in tree lengths for skidding to the concentration point for machine bucking and loading is the most advantageous economically.

Prof. Carter: Is bundling being tried?

Mr. Koski: Several experimental bundling operations are being tried in Upper Michigan. No definite conclusions as to the merits of bundling over the conventional handling methods have as yet been derived.

R. R. Edgar (William Bonifas Lumber Company): Small pulpwood operations are now the rule in the Lake States due to the nature of the present-day pulpwood stands. Present-day stands are scattered and have relatively low per-acre volumes. Good forestry practice will require many small operations, operating over a large area. The use of costly mechanical equipment on such operations is not always economically sound. This is especially true where the work is done by farmers who devote only a portion of their time to pulpwood production. This type of farmer-jobber generally finances his own operations (apart from stumpage) and equipment with a high initial cost is beyond his financial means. The high cost of operations resulting from the use of primitive logging techniques is partially offset by a lower overhead cost than is possible on company-run operations. Equipment that can be used on both the farm and on logging operations may lead to advances in mechanization and lower costs.

Mr. Koski: Mr. Edgar's statements are true as applied to Michigan and Wisconsin and to some parts of Minnesota. However, on larger holdings which still exist in Minnesota, mechanized operations, if properly conducted with the appropriate mechanical equipment, can be the most economical means of operation.

W. S. Bromley (American Pulpwood Association): Mr. Koski's paper gives a very clear picture of how pulpwood is logged on most operations in the Lake States. I shall not attempt to add anything to his paper. In reviewing it, the members of the Forest Products Research Society, may want to hear how pulpwood logging practices in other parts of the

country may differ from that conducted in the Lake States and described so well by Mr. Koski.

The felling and bucking of pulpwood in other regions of the country differs materially from the manner in which it is handled in the Lake States, only on the following points:

1. Most of the pulpwood cut and felled in the Lake States is prepared in 100 inch or 8-foot lengths, while in the South a large portion is cut in lengths of close to 5 feet, and in the East and Northeastern part of the country, the most common length is 4 feet or 52 inches.

2. More of the Scandinavian bow type saws are used in the Lake States than in the South. In this Northern region very few of the circular type of mechanized saws are used, while they are very common to the Southern region.

3. The density of undergrowth and saplings and the deep winter snowfalls on most of the sites on which pulpwood is felled in the Lake States makes it necessary for wood to be felled or piled with very definite patterns so that it is ready for skidding or winter hauling. Sawyers usually work with definite strips in which the skidding trail is usually located in the middle of their felling area. This is a phase of pulpwood logging in the Lake States that is very often omitted in some of the Southern operations, especially where trucks are able to go right to the pulpwood piles or stump without any intermediate skidding.

As Mr. Koski pointed out, the use of tree length skidding in the Lake States is definitely increasing. At the present time, however, it can be said that you will see more tree length skidding in other regions of the country. The use of drays and sleighs in skidding are, of course, more common to the Lake States and New England regions than to the South.

The tendency to provide for the mechanical loading and unloading of pulpwood has probably received greater impetus in the Lake States than in any other part of the country. This is due to the pulpwood being cut into longer lengths than in the other pulpwood regions. It should be noted that it is becoming increasingly difficult to get the average younger men engaged in pulpwood operations to manhandle the 8 foot lengths of pulpwood. Even where the small bobtail trucks are being used, it is found that more than half of the trucks have been equipped with some form of a winch or hoist which enables the operator to load or unload his truck with the minimum of effort.

As Mr. Koski pointed out, there is a definite trend in the Lake States toward the use of more trailers in hauling pulpwood. This trend ties in very definitely to the increased use and application of mechanical loading and unloading of trucks. Until you provide for very rapid loading and unloading, it is not practical or profitable to make use of the larger trucks and heavier trailer equipment. At the present time, however, it seems that there is considerably more use of trailers in Northern Minnesota than in the other Lake States.

Except for the points I have mentioned, pulpwood logging in other parts of the country does not differ materially from the manner in which Mr. Koski has outlined for the Lake States. In closing my comments, I want to repeat that he has given you a very comprehensive view of pulpwood operations and handling in the Lake States.

Mr. Koski: Mr. Bromley has ably pointed out most of the differences in the pulpwood logging in the Lake States and in that carried on in other parts of the United States.

TECHNICAL SESSION II

Monday, May 2, 1949, 1:00 P. M.

General Subject: Furniture and Plywood

Chairman: C. F. Van Epps, Materials Engineering Department, Stromberg–Carlson Company, Rochester, New York *(Northeast Regional Board Member, FPRS)*

Recorder: Richard A. Hertzler, Southeastern Forest Experiment Station, Asheville, North Carolina *(Secretary-Treasurer, Virginia–Carolinas Section, FPRS)*

Tropical Wood Research for the Furniture Industry

Frederick F. Wangaard
Yale University

This is a summary of some of the work on the evaluation of tropical woods underway at the Yale School of Forestry for the Office of Naval Research, Navy Department.

Positive identification of species was assured through the selection of representative standing trees by botanists, foresters and lumbermen, and was aided by collection of herbarium specimens and comparison of materials with the Yale wood collection of 45,000 specimens. The mechanical, physical, seasoning, machining, and steam bending properties of 12 tropical woods are compared with such established furniture woods as black cherry, mahogany, black walnut, sugar maple, and white oak. Judging from these comparisons, several of the tropical species repo ted on appear to possess properties that would make them valuable additions to our list of tropical furniture species.

Introduction

THE increasing difficulty of obtaining adequate supplies of lumber, veneer, and other wood products, particularly in the higher grades of domestic hardwoods, emphasizes the need for research to determine the adaptability of woods obtainable from other sources. Attention turns quite naturally to the largest remaining reservoir of timber wealth—the tropics. Although the vast forests of the tropics contain a large number of timber species that appear to possess desirable properties, adequate technical data are available for very few of them. The known general characteristics of certain of these tropical species indicate the possibility that they may be superior to the woods now used for a number of special purposes.

The School of Forestry at Yale University has been actively engaged in research in the field of tropical woods for more than twenty-five years, during which time it has built up a collection that now contains over 45,000 specimens of wood, mostly tropical in origin. In 1947 the scope of these activities was expanded to meet the growing need for technical data relating to the properties of these woods. Under the sponsorship of the Navy Department through the Office of Naval Research, studies were initiated to determine the basic properties of a selected group of tropical American timbers and to evaluate each species with regard to its potentialities for specific types of use.

In this study direct comparisons are made with well-known species of proved serviceability. Although immediate large-scale commercial acceptance is not anticipated on the basis of these tests, data of this type should serve to arouse the interest of potential producers and consumers. These data should also stimulate further tests and trials to demonstrate the performance of the wood in actual use.

Properties Tested

The general nature of the tests being conducted under this research program is indicated by the following:

1. *Mechanical Properties*
   Representative material from each log is tested in the green and air-dry conditions to determine properties in (1) static bending; (2) compression parallel to grain; (3) compression perpendicular to grain (4) hardness (side and end); (5) shear; (6) tension perpendicular to grain; (7) cleavage; and (8) toughness.
2. *Physical Properties*
   Representative material from each log is tested to determine specific gravity, shrinkage, and decay resistance. Decay resistance is determined by means of an accelerated laboratory test method. Tests to determine rate of moisture absorption, gluing characteristics, and weathering characteristics are conducted on material selected from stock available from several logs of each species. Cooperation with other laboratories has been obtained in conducting tests of resistance of selected species to fire, abrasion, and marine borer attack.

3. *Seasoning Properties*

   Test specimens obtained from each log are used to determine rate of drying and seasoning characteristics (including the development of seasoning defects) under air-drying conditions.

4. *Machining Properties*

   Observations are made and recorded with regard to the general characteristics of each species when subjected to the sawing, planing, shaping, and boring operations involved in the preparation of specimens for mechanical testing.

5. *Steam-Bending Properties*

   Those species that appear from other tests to be adapted to steam bending, are compared directly with white oak of bending quality.

Accurate identification of all test material is provided through the selection of representative standing trees in the forest by botanists, foresters, or lumbermen. Herbarium specimens consisting of leaves, flowers, or fruit from the same tree are collected to "document" the field identification. From each tree, an eight-foot log representing the upper half of the first 16-foot log taken above the butt swell is marked and shipped to New Haven where it is sawed into test blanks under close supervision. Further assurance of correct identification is provided by direct comparison of the wood with authentic specimens from the Yale collections. A minimum of three trees is sought for each species studied, and an attempt is made to secure representative material from various portions of its geographic range.

The first shipment of logs received under this project arrived in New Haven in April 1947. Since that time nearly 250 logs representing 95 different species have been received. To date, tests to determine the basic physical and mechanical properties of these woods have been completed on material representing 43 species. Mechanical test data collected thus far are largely limited to the properties of the unseasoned wood. A comprehensive technical report dealing with 25 of these species for which sufficiently representative data have been obtained is now in preparation and will be published in the near future.

It is the purpose of this paper to discuss the results of tests conducted upon tropical woods that appear to be potentialiy useful in furniture manufacture. Many of these woods enjoy a local reputation in various furniture applications and a few are already more or less widely known in the industry. Even though acceptability of a wood has become established, systematic study of its technical properties may help to develop a fuller realization of its potentialities and proper utilization.

The characteristics desired in a furniture wood vary with the specific application. Few wood products call for a greater diversification of technical qualities and characteristics than does furniture with its multiplicity of variously machined solid components including turnings and carvings, core stock for glued construction, figured and plain face veneers, crossbands and interior-plies, hidden and exposed parts, and shaped, molded, or bent members.

Among the characteristics that influence the choice of a particular wood for use in one or more furniture applications are suitable density and such mechanical properties as hardness, bending strength, compressive strength, shear strength, and resistance to cleavage. Low shrinkage properties are advantageous in most furniture uses. Appearance, including color, grain, texture, and figure, together with good machining and finishing characteristics, are among the important factors considered in the choice of woods used in exposed parts of furniture. Also included among the desirable characteristics for furniture are ease of gluing and mechanical fastening. The suitability of a species for veneer is obviously limited by its adaptability to the processing involved in veneer cutting and drying. Suitable air drying and kiln drying characteristics are essential to all lumber applications in furniture.

An evaluation based on all of these factors is not possible in this paper. However, pertinent data are presented relative to the density, mechanical properties, shrinkage, and seasoning characteristics of a dozen tropical American species, together with directly comparable data for a number of domestic woods that are well known in the furniture field.

Although the characteristics of the woods under consideration have, for ease of evaluation, been intentionally compared with those

TABLE 1.—STRENGTH PROPERTIES OF TWELVE TROPICAL AMERICAN WOODS IN COMPARISON WITH REPRESENTATIVE WOODS USED IN FURNITURE CONSTRUCTION

Species	Source	No. of logs	Moisture content	Specific Gravity		Static Bending				
						Fiber stress at proportional limit	Modulus of rupture	Modulus of elasticity	Work to proportional limit	Work to maximum load
			percent	Oven-dry Vol.	Green Vol.	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	in.-lb. per cu. in.	in.-lb. per cu. in.
Goncalo alves (*Astronium graveolens*)	Honduras	3	49.2	0.92	0.81	7,740	11,600	1,950	1.87	7.2
Courbaril (*Hymenaea courbaril*)	Honduras, Surinam, Puerto Rico	6	59.9	0.80	0.70	6,890	12,180	1,640	1.62	14.1
Tatajuba (*Bagassa guianensis*)	Brazil	2+	58.0	0.76	0.68	10,340	14,510	2,300	2.84	11.8
Nargusta (*Terminalia amazonia*)	British Guiana, British Honduras	6	72.3	0.76	0.66	8,140	12,720	2,160	1.79	11.4
White oak[1] (*Quercus alba*)	United States	---	68	0.71	0.60	4,700	8,300	1,250	1.08	11.6
Angelique (*Dicorynia paraensis*)	Surinam	2	78.7	0.69	0.60	7,650	11,410	1,840	1.78	12.0
Yellow sanders (*Buchenavia capitata*)	Puerto Rico	3	65.1	0.66	0.60	6,330	10,050	1,460	1.62	8.8
Sugar maple[1] (*Acer saccharum*)	United States	---	58	0.68	0.56	5,100	9,400	1,550	1.03	13.3
Hububalli (*Loxopterygium Sagotii*)	British Guiana, Surinam	4	98.4	0.62	0.56	5,740	9,380	1,680	1.20	7.6
Frijolillo (*Pseudosamanea guachapele*)	Honduras	3	60.4	0.62	0.56	4,920	8,190	1,200	1.11	9.2
Yellow birch[1] (*Betula lutea*)	United States	---	67	0.66	0.55	4,200	8,300	1,500	0.70	16.1
Roble blanco (*Tabebuia pentaphylla*)	British Honduras, Honduras	6	67.8	0.58	0.52	6,140	10,460	1,870	1.54	11.2
Black walnut[1] (*Juglans nigra*)	United States	---	81	0.56	0.51	5,400	9,500	1,420	1.16	14.6
Black cherry[1] (*Prunus serotina*)	United States	---	55	0.53	0.47	4,200	8,000	1,310	0.80	12.8
Mahogany[1] (*Swietenia macrophylla*)	Central America	---	58	0.50	0.45	6,120	9,240	1,290	----	10.2
Red gum[1] (*Liquidambar styraciflua*)	United States	---	81	0.53	0.44	3,700	6,800	1,150	0.81	9.4
Laurel blanco (*Cordia alliodora*)	British Honduras, Honduras, Nicaragua	10	122.2	0.46	0.42	5,350	8,720	1,170	1.46	9.8
Cedro granadino (*Cedrela Tonduzii*)	Panama	8	67.4	0.46	0.41	4,520	7,510	1,810	0.94	7.1
Prima vera (*Tabebuia Donnell-Smithii*)	Honduras	4	61.5	0.44	0.40	4,230	7,160	970	1.04	6.8

of well established species, it is not intended to imply that woods of unlike characteristics have no place in furniture. Quite the contrary. Through changes in design associated with the adoption of any new industrial material, new woods may be found to satisfy demands that were previously unfulfilled by conventional materials. As an illustration, the use of resin-impregnated densified wood in the legs of office furniture led to an improvement over the performance of natural wood with respect to marring and splintering. There is no reason why one or more of the denser woods available from the tropics should not be equally satisfactory for this purpose.

Mechanical Properties and Density

In general, the mechanical test methods outlined in American Society for Testing Materials Specification D-143 have been followed. Mechanical testing to date has been largely limited to tests of wood in the green condition and, with the exception of toughness values, the strength data in Table 1 are based upon tests of unseasoned material. Toughness values represent an average of results obtained in both the green and air-dry conditions. In the table, twelve tropical woods potentially useful in furniture have been arranged, together with a number of domestic furniture woods, in order of decreasing density so that comparison may be facilitated.

Shrinkage

The shrinkage characteristics of a wood are among the most important properties affecting its successful application in furniture. Some of the unhappy results traceable to excessive shrinkage include components that fail to fit, warping, checking and splitting, failure of glue

TABLE 1.—STRENGTH PROPERTIES OF TWELVE TROPICAL AMERICAN WOODS IN COMPARISON WITH REPRESENTATIVE WOODS USED IN FURNITURE CONSTRUCTION—Continued

Species	Compression Parallel to Grain: Fiber stress at proportional limit	Compression Parallel to Grain: Maximum crushing strength	Compression Parallel to Grain: Modulus of elasticity	Hardness: End	Hardness: Side	Compression perpendicular to grain	Tension perpendicular to grain	Shear	Cleavage	Toughness[2]
	lb. per sq. in.	lb. per sq. in.	1000 lb. per sq. in.	lb.	lb.	Stress at proportional limit lb. per sq. in.	lb. per sq. in.	lb. per sq. in.	lb. per in. of width	in.-lb. per specimen
Goncalo alves (*Astronium graveolens*)	8,710	5,720	2,410	1530	1700	1740	600	1640	320	151.7
Courbaril (*Hymenaea courbaril*)	8,820	5,340	1,770	1780	1970	1810	1290	1800	570	214.6
Tatajuba (*Bagassa guianensis*)	6,060	7,900	2,510	1620	1670	1200	650	1670	370	195.5
Nargusta (*Terminalia amazonia*)	4,700	5,960	2,460	1460	1440	1260	880	1500	420	198.4
White oak[1] (*Quercus alba*)	3,090	3,560	-----	1120	1060	830	770	1250	420	-----
Angelique (*Dicorynia paraensis*)	4,810	5,590	2,180	1100	1100	1000	700	1340	340	151.2
Yellow sanders (*Buchenavia capitata*)	3,790	5,130	1,570	1350	1230	1070	800	1340	440	122.8
Sugar maple[1] (*Acer saccharum*)	2,850	4,020	-----	1070	970	800	----	1460	----	-----
Hububalli (*Loxopterygium Sagotii*)	3,790	4,700	1,920	960	1040	1060	660	1200	370	110.8
Frijolillo (*Pseudosamanea guachapele*)	2,790	3,930	1,410	1060	1030	960	710	1270	310	130.3
Yellow birch[1] (*Betula lutea*)	2,620	3,380	-----	810	780	530	430	1110	270	-----
Roble blanco (*Tabebuia pentaphylla*)	3,860	4,720	1,520	1100	960	860	800	1290	410	152.3
Black walnut[1] (*Juglans nigra*)	3,520	4,300	-----	960	900	600	570	1220	360	-- --
Black cherry[1] (*Prunus serotina*)	2,940	3,540	-----	750	660	440	570	1130	330	-----
Mahogany[1] (*Swietenia macrophylla*)	-----	4,540	-----	750	650	710	----	1310	----	-----
Red gum[1] (*Liquidambar styraciflua*)	2,230	2,840	-----	630	520	460	510	1070	330	-----
Laurel blanco (*Cordia alliodora*)	3,370	3,910	1,310	820	740	700	520	1090	270	131.7
Cedro granadino (*Cedrela Tonduzii*)	2,770	3,370	1,330	650	550	600	430	990	260	106.2
Prima vera (*Tabebuia Donnell-Smithii*)	2,900	3,550	1,050	810	690	780	730	1050	320	72.0

[1] Data from Forest Products Laboratory, Madison, Wis.

[2] Toughness values are the average of tests of green and air-dry specimens 5/8 x 5/8 x 10 inches loaded on the tangential face over an 8-inch span.

joints, and even the rupture of crossband and face veneers. It has long been recognized that, as a general rule, favorable low shrinkage properties are associated with a correspondingly low density. A notable exception to this general relationship is black locust with shrinkage values comparable to those of the lighter hardwoods in spite of its relatively high density. Since other desirable properties including mar resistance, strength, certain machining characteristics, and ability to hold mechanical fastenings are associated with high density, the user is confronted with the problem of compromising between the ideal wood in these respects in order to obtain satisfactory performance from the standpoint of shrinkage.

The relationship between volumetric shrinkage and specific gravity is shown for a representative group of domestic hardwoods and for a group of tropical hardwoods in Fig. 1. Although increasing density is commonly associated with greater shrinkage in both groups, it is evident that most of the tropical woods are characterized by lower shrinkage values than home-grown hardwoods of comparable density. Even the extremely dense tropical woods (specific gravity of 0.80–0.90) show appreciably less shrinkage than is commonly displayed by domestic woods only three-fourths as heavy. The widely recognized dimensional stability of mahogany and teak is substantiated by their position on the graph, but it is also evident that a number of other tropical woods approach these two species in this respect.

Values for radial, tangential, and volumetric shrinkage from the green to oven-dry condition are shown in Table 2 for twelve tropical woods and a number of well-known furniture woods.

Seasoning Characteristics[1]

The air-seasoning characteristics of each of these species have been observed in the course of air drying 2x2 in. squares and 5/4 in. boards. Each species has been evaluated with respect to rate of drying, tendency to warp, check, or split, and development of seasoning stresses. Results of these observations and determinations are presented in Table 3, which also includes an over-all rating of seasoning characteristics under the heading "Seasoning Classification".

Species Descriptions[2]

1. *Astronium graveolens* Jacq.

GONCALO ALVES

Astronium is an important genus including about a dozen species of medium to large timber trees occurring throughout Tropical America from southern Mexico to Argentina. Gonçalo alves is characteristic of a distinct section of the genus *Astronium* in which the wood is marked with blackish bands of variable size and spacing.

Seasoned heartwood yellowish to dark brown or reddish, usually with a conspicuous blackish striping. Sapwood moderately wide (two to four inches), sharply demarcated, pale brown tinged with gray. Grain variable, straight to roelike, often producing a pleasing stripe on the quarter-sawed surface. Texture fine, uniform; growth layers indistinct. The wood often displays a striking figure as a result of the irregular occurrence of dark longitudinal bands. Odor and taste not distinctive. Exceedingly heavy, comparable in this respect to greenheart with an average specific gravity of 0.81 (0.72 to 0.94) based on oven-dry weight and green volume. Weight per cubic foot averages 75 pounds in the green condition and 60 pounds when air dry.

[1] Data on seasoning characteristics have been collected under the direction of Prof. Fred E. Dickinson, Yale School of Forestry.

[2] Some of the information presented in this section is based upon descriptions contained in *"Timbers of the New World"*, by Samuel J. Record and Robert W. Hess, published by Yale University Press in 1943.

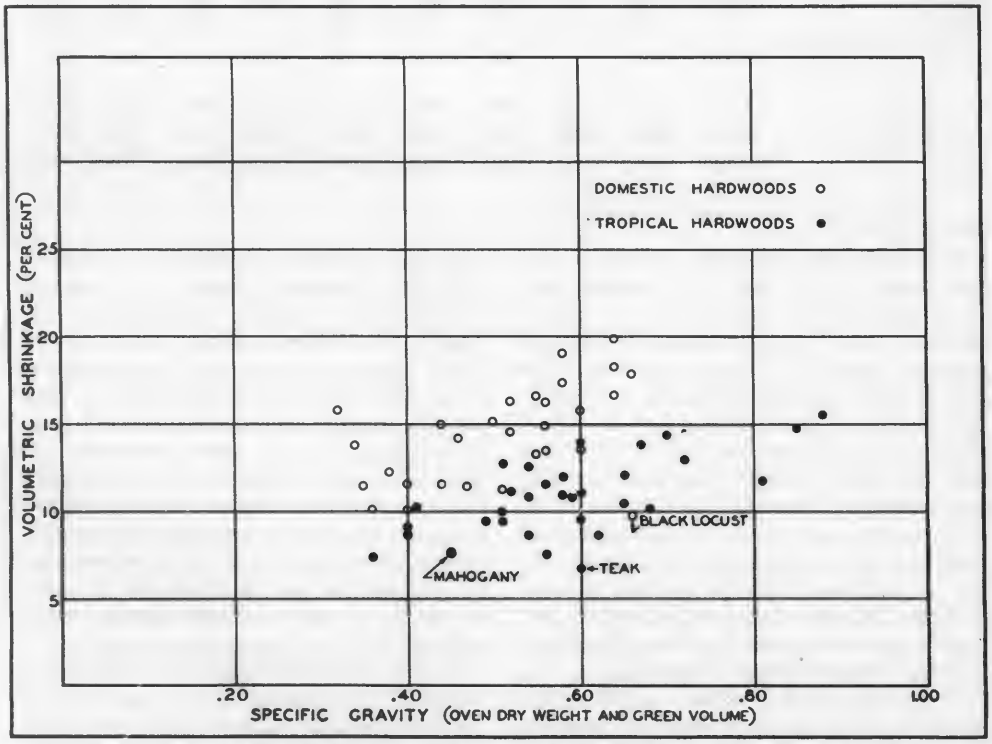

Fig. 1.—Comparative shrinkage values for representative tropical and domestic hardwoods.

TABLE 2.—SHRINKAGE PROPERTIES OF TWELVE TROPICAL AMERICAN WOODS COMPARED WITH WELL-KNOWN FURNITURE WOODS

Species	Source	Specific Gravity	Shrinkage (percent)		
			Radial	Tangential	Volumetric
		Green volume basis			
Goncalo alves (*Astronium graveolens*)	Honduras	0.81	3.8	7.7	11.8
Courbaril (*Hymenaea courbaril*)	Honduras, Surinam, Puerto Rico	.70	4.4	8.6	12.6
Tatajuba (*Bagassa guianensis*)	Brazil	.68	5.2	6.6	10.2
Nargusta (*Terminalia amazonia*)	British Guiana, British Honduras	.66	5.0	8.0	12.8
White oak[1] (*Quercus alba*)	United States	.60	5.3	9.0	15.8
Angelique (*Dicorynia paraensis*)	Surinam	.60	4.6	8.2	14.0
Yellow sanders (*Buchenavia capitata*)	Puerto Rico	.60	2.8	5.7	9.6
Sugar maple[1] (*Acer saccharum*)	United States	.56	4.9	9.5	14.9
Hububalli (*Loxopterygium Sagotii*)	British Guiana, Surinam	.56	3.4	7.2	11.1
Frijolillo (*Pseudosamanea guachapele*)	Honduras	.56	2.9	4.5	7.6
Yellow birch[1] (*Betula lutea*)	United States	.55	7.2	9.2	16.7
Roble blanco (*Tabebuia pentaphylla*)	British Honduras, Honduras	.52	3.6	6.0	9.1
Black walnut[1] (*Juglans nigra*)	United States	.51	5.2	7.1	11.3
Black cherry[1] (*Prunus serotina*)	United States	.47	3.7	7.1	11.5
Mahogany[1] (*Swietenia macrophylla*)	Central America	.45	3.5	4.8	7.7
Red gum[1] (*Liquidambar styraciflua*)	United States	.44	5.2	9.0	15.0
Laurel blanco (*Cordia alliodora*)	British Honduras, Honduras, Nicaragua	.42	3.1	6.7	8.7
Cedro granadino (*Cedrela Tonduzii*)	Panama	.41	4.2	6.3	10.3
Prima vera (*Tabebuia Donnell-Smithii*)	Honduras	.40	3.1	5.2	8.7

[1] Data from Forest Products Laboratory, Madison, Wis.

TABLE 3.—SEASONING CHARACTERISTICS OF TWELVE TROPICAL AMERICAN WOODS HAVING POTENTIAL APPLICATIONS IN FURNITURE

Species	Source	Rate of drying[1]	Warping[2]			Checking and splitting[2]		Case-hardening[3]	Seasoning classification[4]
			Crook & Bow	Cup	Twist	End	Surface		
Goncalo alves (*Astronium graveolens*)	Honduras	Moderate	C	B	C	C	B	A	II
Courbaril (*Hymenaea courbaril*)	Honduras, Surinam, Puerto Rico	Fast to Moderate	B-C	A-B	A-B	A-B	A-B	A-C	II
Tatajuba (*Bagassa guianensis*)	Brazil	Moderate	B	A	B	A	A	A	II
Nargusta (*Terminalia amazonia*)	British Guiana, British Honduras	Fast to Moderate	B	A	A	A-D	A-C	A	I-III
Angelique (*Dicorynia paraensis*)	Surinam	Fast	B	B	A	C	C	C	II
Yellow sanders (*Buchenavia capitata*)	Puerto Rico	Fast	B	A	A	B	B	A	I
Hububalli (*Loxopterygium Sagotii*)	British Guiana, Surinam	Fast to Moderate	B-C	A-B	A-B	A-D	A-D	A	I-II
Frijolillo (*Pseudosamanea guachapele*)	Honduras	Moderate	C	A	A	A	A	A	I
Roble blanco (*Tabebuia pentaphylla*)	Birtish Honduras, Honduras	Fast	B	A-B	A	A	A-B	B	I
Laurel blanco (*Cerdia alliodora*)	British Honduras, Honduras, Nicaragua	Fast	A-B	A-B	A-B	A-B	A-B	A	I
Cedro granadino (*Cedrela Tonduzii*)	Panama	Fast	A	A	A	A	A	A	I
Prime vera (*Tabebuia Donnell-Smithii*)	Honduras	Fast	B	A	B	A	A	A	I

[1] Rate of drying based on April to November air-seasoning conditions in New Haven, Conn.
Fast: Less than 120 days from green condition to 16 percent moisture content.
Moderate: 120 to 200 days from green condition to 16 percent moisture content.
Slow: More than 200 days from green condition to 16 percent moisture content.
[2] Warping, checking, and splitting: A—None; B—Slight; C—Moderate; D—Severe.
[3] Casehardening: A—None; B—Slight; C—Severe.
[4] Seasoning Classification: I —Easy to season (comparable to mahogany and yellow poplar);
II —Moderately difficult to season (comparable to red gum and yellow birch);
III—Difficult to season (comparable to white oak and beech).

Based on observation of a limited amount of material from Honduras, the wood should be seasoned at a moderate to slow rate to avoid excessive checking and warping.

The mechanical properties of *Astronium graveolens* are considerably higher in most respects than any well-known domestic species. In comparison with white oak, the wood is markedly stronger in all properties for which comparable data are available, except tension across the grain and cleavage, for which white oak shows a slight advantage.

Shrinkage is moderately low, especially in consideration of the high density of the wood. Volumetric shrinkage of 11.8 percent is comparable to that of black walnut and considerably less than that of white oak. Radial shrinkage of 3.8 percent is especially low; tangential shrinkage of 7.7 percent is intermediate to that of black walnut and white oak. The ratio of tangential to radial shrinkage is relatively high, indicative of non-uniform shrinkage in these two directions.

2. *Bagassa guianensis* Aubl. TATAJUBA

Tatajuba is a large forest tree of rather infrequent occurrence throughout the Guianas and the Amazon region of Brazil.

Seasoned heartwood lustrous golden brown to russet. Sapwood narrow, sharply demarcated, pale yellow to nearly white. Grain usually interlocked, resulting in a rather broad stripe figure on the radial surface. Texture medium to coarse, moderately uniform; growth layers indistinct. Odor and taste not distinctive when seasoned. Very heavy, comparable to hickory, with an average specific gravity of 0.68 (0.62 to 0.71) based on oven-dry weight and green volume. Weight per cubic foot averages 67 pounds in the green condition and 50 pounds when air dry.

The wood air seasons at a moderate rate with very little tendency to warp or check, based on observations of a limited amount of material from Brazil.

The strength properties of *Bagassa guianensis* in the green condition exceed those of any well-known domestic timber. Although only slightly heavier than hickory, it exceeds that species in all properties for which comparable data are available except work to maximum load in static bending. The margin of difference is particularly conspicuous in elastic resilience, stiffness, and crushing strength. The superiority of tatajuba is even more evident in a general comparison with white oak, although here the values for tension across the grain and cleavage are somewhat below those for oak.

Shrinkage is exceptionally low among species of comparable high density. Volumetric shrinkage of 10.2 percent is only two-thirds that of oak and approximately the same as that of black locust, a slightly lighter North American species, noted for its dimensional stability. Values for radial shrinkage of 5.2 percent and tangential shrinkage of 6.6 percent are indicative of unusual uniformity in these two directions.

3. *Buchenavia capitata* (Vahl.) Eich. YELLOW SANDERS

Yellow Sanders is a tree of the West Indies and tropical South America attaining a height of 80 feet and a diameter of 3 feet above large buttresses.

Seasoned heartwood yellow- to golden-brown usually with a gray or olive hue. Sapwood light yellow-brown. Grain more or less interlocked, producing a distinct roe figure on the radial surface and an attractive figure on the tangential surface characterized by the wavy course of the prominent vessels; texture medium to rather coarse, uniform; growth layers not distinct. Faint spicy odor and mildly bitter taste when seasoned. Heavy to very heavy, comparable to white oak, with an average specific gravity of 0.60 (0.52 to 0.67) based on oven-dry weight and green volume. Weight per cubic foot averages 62 pounds in the green condition and 44 pounds when air dry.

Observations made on a limited sample of material of this species indicate that it can be air seasoned at a fast rate with only slight warping and checking developing. It compares in air-seasoning characteristics with yellow poplar.

When compared with other woods of similar density, *Buchenavia capitata* is approximately average in static-bending strength and elastic resilience (as measured by work to propor-

tional limit), crushing strength, compression across the grain, shear, and toughness. It is above average in hardness, slightly above average in tension perpendicular to grain and cleavage resistance, and somewhat below average in stiffness and shock resistance as measured by work to maximum load in static bending. Yellow sanders exceeds white oak in all properties except work to maximum load in which it is approximately three-fourths as strong.

Shrinkage is exceptionally low among woods of comparable density. In volumetric shrinkage, with a value of 9.6 percent, it is far more stable than white oak and may be classed with black locust and teak, both of which are noted for their exceptionally low shrinkage. On the basis of its low shrinkage of 2.8 percent radially and of 5.7 percent tangentially, the wood is nearly comparable to teak, although the high ratio of tangential to radial shrinkage is indicative of somewhat less uniformity than teak in this characteristic.

4. *Cedrela Tonduzii* C. DC.

CEDRO GRANADINO

Cedro granadino is a large tree, one of many closely related species of the genus *Cedrela.* Species of *Cedrela* grow in every country of the New World south of the United States except Chile, but Cedro granadino is found in Panama and Costa Rica.

Heartwood becoming rich red brown upon exposure and drying. Sapwood pinkish, two to four inches wide, clearly demarcated from the heartwood. Grain usually straight; texture medium, uniform; growth layers delineated by inconspicuous light lines. General appearance chiefly characterized by scattered lines of vessels on a plain background with a satiny sheen. No perceptible odor or characteristic taste when seasoned. Moderately light, comparable to Port Orford cedar, with a specific gravity of 0.41 (0.32 to 0.45) based on oven-dry weight and green volume. Weight per cubic foot averages 43 pounds in the green condition and 31 pounds when air dry.

The wood air seasons readily and may be dried at a fast rate with no apparent damage. It compares very favorably with eastern white pine in its seasoning characteristics.

Cedrela Tonduzii is intermediate to Port Orford cedar and mahogany in density as well as in most properties for which comparable data are available. It is comparable to mahogany in stiffness and shows a degree of shock resistance approximately equal to that of Port Orford cedar.

Cedra granadino is characterized by moderate shrinkage. Radial shrinkage of 4.2 percent, tangential of 6.3 percent, and volumetric shrinkage of 10.3 percent, correspond closely in magnitude to shrinkage values for Port Orford cedar, and are somewhat more uniform and numerically less than values for yellow poplar, a lighter wood.

5. *Cordia alliodora* (R. and P.) Cham.

LAUREL BLANCO

Laurel blanco is a medium to large tree widely distributed in the West Indies and throughout Central America and the South American tropics.

Heartwood drying to a pale golden brown to brown with dark streaks. Sapwood one to three inches wide, not sharply demarcated, yellowish to light brown. Grain generally straight, sometimes interlocked; texture fine to medium, uniform; growth rings delineated by narrow dark streaks as seen on side-grain surfaces. Small dark rays give the wood a mottled appearance on the radial surface. No distinctive odor or taste except in the darker colored specimens which have a distinct spicy odor. Moderately light to moderately heavy, comparable to mahogany, with an average specific gravity of 0.42 (0.31 to 0.56) based on oven-dry weight and green volume. Weight per cubic foot averages 58 pounds in the green condition and 31 pounds when air dry.

The wood air seasons rapidly. Only a slight amount of checking and warping result from rapid air drying. It is comparable to yellow poplar in its seasoning characteristics.

The mechanical properties of laurel blanco are above average for woods of comparable density in all static-bending properties except stiffness. With the exception of hardness, strength values are intermediate to those of mahogany, a slightly heavier wood, and Alaska cedar, characterized by the same density as *Cordia alliodora.* In hardness laurel blanco exceeds mahogany by an appreciable margin.

Shrinkage is relatively low. Volumetric shrinkage of 8.7 percent is intermediate be-

tween that of mahogany and Alaska cedar. Radial and tangential shrinkage values of 3.1 percent and 6.7 percent respectively are in about the same ratio as Alaska cedar, indicative of non-uniform shrinkage in these two directions in contrast to the exceptionally uniform shrinkage of mahogany.

6. *Dicorynia paraensis* Benth. ANGELIQUE

Angelique is a large tree growing to a height of 150 feet and a diameter of 5 feet in the Amazon basin and the Guianas.

Seasoned heartwood brown or gray brown, often with a purplish tinge, and frequently characterized by dark brown streaks; distinctly lustrous. Sapwood narrow, sharply demarcated, light brown. Grain usually straight. Texture medium, uniform, although vessels are prominent as long brown lines on side-grain surfaces producing an attractive figure somewhat resembling that of walnut; growth layers indistinct, ripple marks present. Heartwood without a distinctive odor or taste when seasoned. Heavy to very heavy, comparable to white oak, with an average specific gravity of 0.60 (0.54 to 0.63) based on oven-dry weight and green volume. Weight per cubic foot averages 67 pounds in the green condition and 45 pounds when air dry.

The wood has a tendency to check and split in drying and should be air seasoned at a moderate to slow rate to minimize these defects. Thick stock tends to become severely case-hardened.

In most of its mechanical properties in the green condition, *Dicorynia paraensis* is similar to teak which is characterized by the same average density. Comparison with white oak shows a distinct margin of superiority over oak in bending properties, except for work to maximum load in which the two species are nearly identical. Angelique is almost 50 percent stiffer than oak. Crushing strength is also notably higher than for oak, but smaller and sometimes insignificant differences are shown for the remaining properties that are compared. The comparison with teak is quite consistent throughout, indicative of the close similarity of the two woods from a mechanical standpoint.

Shrinkage values are comparable to such well-known domestic woods as red oak and hard maple. Volumetric shrinkage of 14.0 percent is intermediate to that of maple and oak; radial shrinkage of 4.6 percent and tangential shrinkage of 8.2 percent are also comparable in magnitude and ratio to these two species. In all respects its shrinkage is about twice that of teak, which it so closely resembles in mechanical properties.

Results of ash-content determinations, made on Surinam specimens as a part of the current study, show that the heartwood has an average ash content of 0.32 percent including a silica content of 0.28 percent. Although the over-all ash content is not extraordinary, the silica content is exceptionally high and warrants further study from the standpoint of its possible dulling effect on woodworking saws and knives.

7. *Hymenaea courbaril* L. COURBARIL

Courbaril is a large tree exceeding 100 feet in height and 6 feet or more in diameter. It is widely distributed throughout Tropical America from Mexico and the West Indies to Bolivia.

Seasoned heartwood russet to reddish brown, often with dark streaks. Sapwood generally wide, especially in rapidly grown second-growth trees, white to gray, usually sharply demarcated from the heartwood. Grain commonly interlocked; texture mostly medium, uniform; growth layers not distinct except as limited by a band of terminal parenchyma. The sapwood has an attractive appearance, resembling hard maple on the radial surface, whereas the figure on the tangential surface is distinguished chiefly by its lustrous sheen marked with scattered lines of vessels. The wood has no distinctive odor or taste when seasoned. Very heavy, comparable to North American black locust; with an average specific gravity of 0.70 (0.62 to 0.80) based on oven-dry weight and green volume. Weight per cubic foot averages 70 pounds in the green condition and 52 pounds when air dry.

Observations made on material from Surinam, Honduras, and Puerto Rico indicate that this species can be air seasoned without difficulty at a moderate to fast rate with very little warping or checking. Other reports indicate that material of the same species from Brazil seasons with a minimum of checking and warp-

ing. It compares with black walnut in its drying characteristics.

The mechanical properties of courbaril in the green condition are in general intermediate to those of such well-known strong domestic woods as black locust and shagbark hickory. In comparison with most woods of similar density, courbaril is slightly below the average in bending strength, stiffness, and crushing strength, and somewhat above average in shock resistance, hardness, compression perpendicular to grain, cleavage, and tension perpendicular to the grain.

Volumetric shrinkage of 12.6 percent is intermediate between that of black locust and shagbark hickory, both woods of somewhat lower density than courbaril. Black locust is characterized, among woods of its weight class, by its exceptionally low shrinkage and *Hymenaea courbaril* also occupies a relatively favorable position in this respect. Although radial shrinkage of 4.4 percent and tangential shrinkage of 8.6 percent are moderate, the ratio of tangential to radial shrinkage values is relatively high, indicative of non-uniform shrinkage.

8. *Loxopterygium Sagotii* Hook. f.
HUBUBALLI

Hububalli is a fairly common tree attaining a height of 100 feet in the forests throughout its range which extends from Venezuela and Guianas to Argentina.

Seasoned heartwood brown or reddish brown characterized by dark brown streaks of irregular width and occurrence. Sapwood two to three inches wide, not distinctly defined. Grain commonly interlocked. Texture medium, uniform; growth layers indistinct. Oil specks evident on the lighter colored surfaces. Heartwood without a distinctive odor or taste when seasoned. Heavy, comparable to yellow birch, with an average specific gravity of 0.56 (0.47 to 0.65) based on oven-dry weight and green volume. Weight per cubic foot averages 69 pounds in the green condition and 41 pounds when air dry.

The wood appears to vary greatly in its seasoning characteristics. Material from Surinam air-seasoned readily at a fast rate with no checking and only slight warping, whereas that from British Honduras, drying at a moderate rate, developed severe end and surface checks and showed a definite tendency to warp.

The mechanical properties of *Loxopterygium Sagotii* in the green condition are representative, in general, of the majority of woods of comparable density. Although of similar density, it exceeds yellow birch in every strength property except work to maximum load in static bending. In many respects its properties are similar to those of teak. *Loxoptergium Sagotii* is slightly lighter than teak, and somewhat lower in static-bending strength, elastic resilience, shock resistance, and crushing strength. It is similar to teak in stiffness, hardness, compression across the grain, and shear.

Shrinkage is moderate. Average volumetric shrinkage of 11.1 percent is almost identical to that of black walnut, a lighter species. Radial shrinkage of 3.4 percent and tangential shrinkage of 7.2 percent indicate a considerable difference between dimensional changes in these two directions.

9. *Pseudosamanea guachapele* (H.B.K.) Harms
FRIJOLILLO

Frijolillo is a medium to large tree found from Guatemala and Salvador to Venezuela and Ecuador.

Seasoned heartwood yellow-brown or rich brown, with a golden luster. Sapwood thin, whitish, and rather sharply demarcated from the heartwood. Grain interlocked to a pronounced degree, producing a conspicuous striped figure on the radial surface. Texture medium to rather coarse, uniform; growth layers indistinct. Tasteless and odorless when seasoned. Heavy, comparable in this respect to hard maple, with an average specific gravity of 0.56 (0.50 to 0.62) based on oven-dry weight and green volume. Weight per cubic foot averages 56 pounds in the green condition and 41 pounds when air dry.

The wood air seasons readily and can be dried at a moderate to fast rate. Warping is the only serious defect and is probably the result of interlocked grain which is prevalent in this species.

Pseudosamanea guachapele with a specific gravity identical to that of hard maple is exceeded by the latter in all strength properties except side hardness and compression perpendicular to the grain. The wood is closely

comparable in most strength properties to white oak.

Frijolillo is characterized by exceptionally low shrinkage. The wood shrinks only about half as much as oak. Volumetric shrinkage of 7.6 percent, radial 2.9 percent, and tangential 4.5 percent are each less than the corresponding value for black locust and closely approach the values for teak.

10. *Tabebuia Donnell–Smithii* Rose
PRIMA VERA

Prima vera is a large tree with a long smooth bole often 4 feet in diameter. Its range extends from Mexico through Guatemala, Salvador, and Honduras.

Heartwood drying to shades of pale yellow to light brown. Sapwood not clearly demarcated, slightly paler than the heartwood. Grain commonly interlocked, producing a pronounced roe figure on the radial surface. Texture medium to rather coarse, uniform; growth layers relatively indistinct; heartwood without characteristic odor or taste when seasoned. Moderately light, comparable to yellow poplar, with an average specific gravity of 0.40 (0.35 to 0.46) based on oven-dry weight and green volume. Weight per cubic foot averages 40 pounds in the green condition and 29 pounds when air dry.

The wood is readily air seasoned and may be dried at a fast rate without serious checking or warping. It is comparable in its drying characteristics to basswood.

On the basis of data from the present study, *Tabebuia Donnell–Smithii* lies well below Central American mahogany, a slightly denser wood, in all strength properties except hardness and compression across the grain. It should be mentioned, however, that previously published data on the properties of prima vera from Honduras show considerably higher strengths in all properties with the exception of hardness, indicating considerable variation in this species. In many respects the properties of the wood are comparable to those of holly. Although holly is 25 percent heavier, prima vera exceeds it in all properties except hardness, shear, and work to maximum load. Only in the latter property is this deficiency at all significant.

The wood is characterized by low shrinkage values comparable to those of Central American mahogany. Radial shrinkage of 3.1 percent is exceptionally low; tangential shrinkage of 5.2 percent and volumetric shrinkage of 8.7 percent are only slightly greater than comparable values for mahogany.

11. *Tabebuia pentaphylla* (L.) Hemsl.
ROBLE BLANCO

Roble blanco is one of the best known and useful trees of Central America. The tree is medium to large, commonly attaining heights of 80–90 feet, in its range extending from Mexico to Ecuador.

Seasoned heartwood grayish brown, finely striped with deep brown. Sapwood narrow, not clearly differentiated from the heartwood, becoming pale brown upon exposure and drying. Grain straight to interlocked, producing a fine, striped figure on the quarter-sawed surface when interlocked. A conspicuous irregular pattern of brown parenchyma characterizes the tangential surface. Texture medium to rather coarse; growth layers visible but not sharply defined; ripple marks present. Heartwood without distinctive odor or taste when seasoned. Heavy, comparable to white ash, with an average specific gravity of 0.52 (0.44 to 0.63) based on oven dry weight and green volume. Weight per cubic foot averages 55 pounds in the green condition and 38 pounds when air dry.

The wood may be air seasoned at a fast rate with little or no checking and only slight warping. In its seasoning properties, it compares favorably with yellow poplar.

In comparison with two well know species in the United States, white ash and white oak, roble blanco is distinctly higher than both in bending strength, elastic resilience, crushing strength, and tension across the grain. It is intermediate to white ash and oak in stiffness, hardness, shear, and cleavage and approximately equal to oak in compression across the grain and shock resistance. This generally favorable comparison is shown in spite of the slightly greater density of ash and a considerably higher density for white oak.

The wood is moderate in shrinkage, intermediate to that of mahogany and black walnut. Volumetric shrinkage is 9.1 percent. Radial

shrinkage of 3.6 percent and tangential of 6.0 percent indicate moderate uniformity in these two directions although the ratio of tangential to radial is greater than in mahogany.

12. *Terminalia amazonia* (Gmel.) Exell
NARGUSTA

Nargusta is a large tree with a long, smooth, buttressed bole occurring from southern Mexico through Central America to the Guianas, Brazil, and Peru.

Heartwood yellow to greenish brown, often streaked or tinged with pink, when freshly cut, becoming slightly darker upon exposure and seasoning. Sapwood two to five inches wide, not clearly differentiated from the heartwood, but somewhat paler. Grain usually straight but sometimes interlocked resulting in a fairly prominent striped figure on the radial surface. Texture medium, uniform, growth layers not clearly defined. No distinctive odor or taste when seasoned. Very heavy, comparable to hickory in this respect, with an average specific gravity of 0.66 (0.53 to 0.77) based on oven-dry weight and green volume. Weight per cubic foot overages 71 pounds in the green condition and 50 pounds when air dry.

Observations of seasoning characteristics of this wood indicate considerable variability. Based on a limited amount of material, *Terminalia amazonia* from British Honduras air dries readily at a fast rate with no checking and only a slight amount of warping, whereas material from British Guiana dries more slowly and both end and surface checking are very pronounced, particularly in thick stock.

The strength properties of nargusta in the green condition are representative of a majority of woods of comparable high density. Higher density and proportionately higher strength properties were found throughout for the British Guiana timber as compared with that from British Honduras. It is not clearly established that such differences may be explained on the basis of geographical origin or whether they represent local variations in site or other growth condition. In this respect, however, it is interesting to observe that similar differences were shown in a previous comparison of this species from British Honduras and Trinidad, the material from British Honduras having the lower density and strength.

In comparison with white oak, *Terminalia amazonia* (based on an average of British Guiana and British Honduras material) is about 10 percent hgher in density, about 50 percent higher in bending strength, hardness, and compression across the grain; about 70 percent higher in crushing strength, elastic resilience, and stiffness; and approximately comparable in tension across the grain, cleavage, shear, and shock resistance.

Shrinkage of the wood is moderate for its density. Volumetric shrinkage averaging 12.8 percent is considerably less than that of hard maple, white oak, or shagbark hickory. Radial shrinkage of 5.0 percent is comparable to that of hard maple; tangential shrinkage of 8.0 percent is less than in maple. The ratio of shrinkage in these two directions indicates moderately uniform shrinkage characteristics.

Discussion

E. S. Harrar (Drexel Furniture Company): Dr. Wangaard's project is very comprehensive in character and undoubtedly will result in the release of much useful information, but as outlined it will not give the furniture manufacturer certain data of the sort he needs on new or little known species. Voluminous mechanical data are of little use to him since case goods are not stress-designed. Good dimensional stability, on the other hand, is a primary requisite of any furniture wood, and I am pleased to see that wood-moisture relationships are being thoroughly investigated.

An adequate and continuous supply of material at a price that will permit of the production of goods in a highly competitive market is a must. Hence, it is suggested that, if possible, you include as a part of your research a study relating to availability or potential availability, how the logs of a given species will break down into lumber grades, and give an approximation, percentagewise, of the volume for each grade per one thousand feet B. M.

In the manufacture of modern and functional furniture, there is a definite trend toward the use of "blonds." To be any use in the furniture industry woods in this category must, of necessity, be uniformly colored. Hence, it might be well to give specific mention to color as well as to report the range in variation if such exists, for each species examined.

Finally, it is also suggested that as a part of your study you endeavor to ascertain suitable ways and means of protecting green logs against the ravages of ambrosia beetles and the attack of fungal stains immediately following extraction from the forest in order that the logs upon their arrival at American ports of entry will have the highest possible market value.

Dr. Wangaard: In reply to Prof. Harrar's comments, I probably should repeat that the data presented in this paper have been collected with a more general objective in mind than suitability for one specific product, such as furniture. Perhaps some of the mechanical data presented are of little concern to the furniture manufacturer who is not designing his product on the basis of mechanical stress. Nevertheless, such information together with data on physical properties furnishes the most exact means available of comparing an unknown wood with one of suitable technical characteristics for a given use.

Insofar as color is concerned, I am in complete agreement with Dr. Harrar as to the importance of noting color variations for each wood. Color descriptions of the woods here reported on are included in the paper.

Prof. Harrar's comments on availability and price are, of course, important. The information gathered in our study as it is now being conducted provides a basis from which it is hoped other studies, particularly in the field of economics, will develop. It does not appear to be feasible to attack simultaneously all of the problems concerned with the introduction of a timber to new markets, but by calling attention to the possibilities of certain tropical woods, we have been encouraged to believe that potential users and producers could be convinced of the value of such studies as Dr. Harrar has mentioned.

E. A. Behr (Chapman Chemical Company): In general have the species, thus far examined, a thick or thin sapwood?

Dr. Wangaard: Sapwood width is noted in the paper under Species Descriptions wherever sufficient data are available. Little generalization is possible in this respect.

Mr. Behr: Have the logs been attacked by insects or stain fungi before they arrived at the testing laboratory?

Dr. Wangaard: Sapwood deterioration in shipment was fairly common both from the standpoint of pinworm holes and staining. In this connection it should be mentioned that no preservative or protective treatment was applied at the point of origin aside from painting the ends of the logs to retard checking.

Mr. Behr: Do you contemplate measuring the treatability of the various species by non-pressure or pressure methods, using oil-soluble type preservatives?

Dr. Wangaard: We have no specific plans at present to investigate the treatability of these woods but believe that such studies would be worth while on selected species of low natural durability.

Mr. Behr: Are data available on the supply, location, and availability of these species?

Dr. Wangaard: Most of the information available on supply of these tropical timbers is rather general in nature. We believe that all of the woods that have been studied so far are available in quantities sufficient to meet any demand that may arise in the near future. It is our hope that sufficient interest will be aroused on the part of potential consumers and suppliers of certain of these timbers to result in field surveys and economic studies that will assist in making their commercial utilization in the United States a reality.

FOREST PRODUCTS RESEARCH SOCIETY

Effect of Plywood Glue Lines on the Accuracy of Moisture-Meter Indications

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The moisture content of plywood as determined with moisture meters was significantly higher for nine of the 10 glues used in the plywood when compared to oven-dry controls. Moisture-meter errors depend on the number of glue lines and the type of glue used in the plywood and the particular moisture meter involved. Errors are probably caused by electrolytes in the glue that become conductors when in contact with moisture in the wood.

Introduction

MANY kinds of glue and many species of wood are used in the manufacture of plywood. Plywood is used for purposes that impose upon it a great variety of exposures to temperature and humidity. It is often desirable to know the moisture content of plywood prior to fabrication. Moisture meters are convenient for determining moisture content of solid wood, but in plywood the glue lines may contain salts or other electrolytes that would be relatively good conductors when moist.

The purpose of this study was to determine the errors of moisture-meter indications when used on plywood.

Material

The material used in the controls and plywood is summarized in the following tabulation.

Species—Douglas-fir
Yellow birch
Number of plies—2, 3, and 5
Thickness of veneer—1/16 inch
Glues—None in controls and 10 in plywood (Table 1)

The glues and gluing data are shown in table 1. There were four hot-press phenols, two intermediate-temperature phenols, one melamine, one resorcinol, one room-temperature-setting urea, and one casein.

All samples were prepared in 12- by 12-inch panels. Glues were mixed, applied, and cured in accordance with the manufacturers' recommendations. Five panels of two, three, and five plies were made with each glue and conditioned for at least one week at 80° F. After conditioning, each panel was trimmed to 10 inches square and cut into four 5-inch squares. One 5-inch square from each panel was placed in each of four conditioning rooms. Thus the four conditioning rooms contained matched sets of samples.

The rooms were maintained at 80° F. and 30, 65, 80, and 90 percent relative humidity. The equilibrium moisture content values for wood in these rooms are approximately 6½, 12, 15, and 19 percent, respectively. Periodic weighings showed that all samples had reached equilibrium at least 6 months before their moisture content was measured.

Apparatus

Apparatus for weighing and measuring the moisture content of the samples is shown in Figs. 1 and 2.

One radio-frequency power-loss and four resistance types of meters were used.

Both needle electrodes and surface contacts were used with the resistance meters. It was

[1] The authors take pleasure in acknowledging the assistance of M. E. Dunlap in planning and giving valuable advice during the progress of the work, of E. C. Peck in the analysis of the data, and of R. F. Blomquist in selecting, formulating, and supplying information on the glues.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

TABLE 1.—GLUING DATA AND FILM pH

Glue and symbol used on graphs	Glue type	Plies	Spread: Douglas-fir	Spread: Yellow birch	Species	Pressing: Pressure	Pressing: Temperature	Pressing: Duration by number of plies: 2	3	5	Film pH
			lb./1000 sq. ft. of single glue line	lb./1000 sq. ft. of single glue line		P.s.i.	°F.	Min.	Min.	Min.	
[1]A ○	Hot-press phenol	2	59.8	44.0	[2]B	250	285	6	8	12	11.5
		3	52.6	44.0							
		5	55.1	44.0	[3]F	175	285	6	8	12	
B ●	Hot-press phenol	2	----	----	B	250	280	4	6	10	11.2
		3									
		5	----	----	F	175	280	4	6	10	
C △	Hot-press phenol	2	1 sheet/line	1 sheet/line	B	250	285	4	6	10	9.5
		3	1 sheet/line	1 sheet/line							
		5	1 sheet/line	1 sheet/line	F	175	285	4	6	10	
D ▲	Hot-press phenol	2	37.0	35.6	B	175	280	5	7	9	9.1
		3	34.5	33.7							
		5	35.6	32.8	F	175	280	5	7	9	
E ▽	Intermediate-temperature phenol	2	29.5	31.2	B	250	260	6	8	10	8.4
		3	30.6	35.0							
		5	29.6	33.7	F	175	260	6	8	10	
F ▼	Intermediate-temperature phenol	2	31.2	29.5	B	250	240	6	8	10	2.2
		3	33.0	28.6							
		5	33.0	28.6	F	175	240	6	8	10	
G □	Hot-press melamine	2	33.4	31.9	B	250	280	5	7	9	6.6
		3	33.21	30.1							
		5	32.8	32.2	F	175	280	5	7	9	
H ■	Resorcinol	2	33.0	27.7	B	250	260	6	8	10	7.2
		3	28.8	28.6							
		5	30.1	33.4	F	175	260	6	8	10	
I ◊	Room-temperature urea	2	56.3	59.8	B	250	75	18 hours			3.6
		3	54.8	52.6							
		5	55.4	55.1	F	175	75				
J ◆	Casein	2	77.0	77.0	B	250	75	18 hours			11.1
		3	77.0	77.0							
		5	77.0	77.0	F	175	75				

[1]This glue was specially formulated to have a high pH.
[2]Yellow birch.
[3]Douglas-fir.

demonstrated by experiment that the electrodes of the four resistance meters could be interchanged with an error of less than 0.5 percent in moisture content. The contactor selected had two needles 9/16 inch apart on each retaining bar, and the pairs were spaced to enter the wood 1-3/16 inches apart. A small clamp was prepared to hold the samples while the needles were being driven. An opening in the base of the clamp permitted the needles to pass completely through the two- and three-ply material without touching the clamp. Leads from the contactor were arranged for quickly connecting and disconnecting the resistance meters.

The 1⅛-inch-diameter aluminum-foil surface contacts were mounted on rubber plugs supported on a type of C-clamp. Samples were clamped between them as shown in Fig. 2.

Electrodes for the radio-frequency power-loss meter were an integral part of the instrument and consisted of concentric metal rings that acted as surface contactors. Samples were placed on a glass plate for moisture-content determinations with this meter.

A triple-beam balance was used to weigh the samples.

Procedure

General

Moisture-content measurements of material in the 30- and 65-percent-relative-humidity rooms were made with the meters located in these same rooms. Samples conditioned in the 80- and 90-percent-relative-humidity rooms were measured in the 30-percent room. This procedure was followed to prevent errors that would result from surface-moisture films that form on objects at high relative humidities. Such films at certain locations on a moisture meter could cause excessively high indications

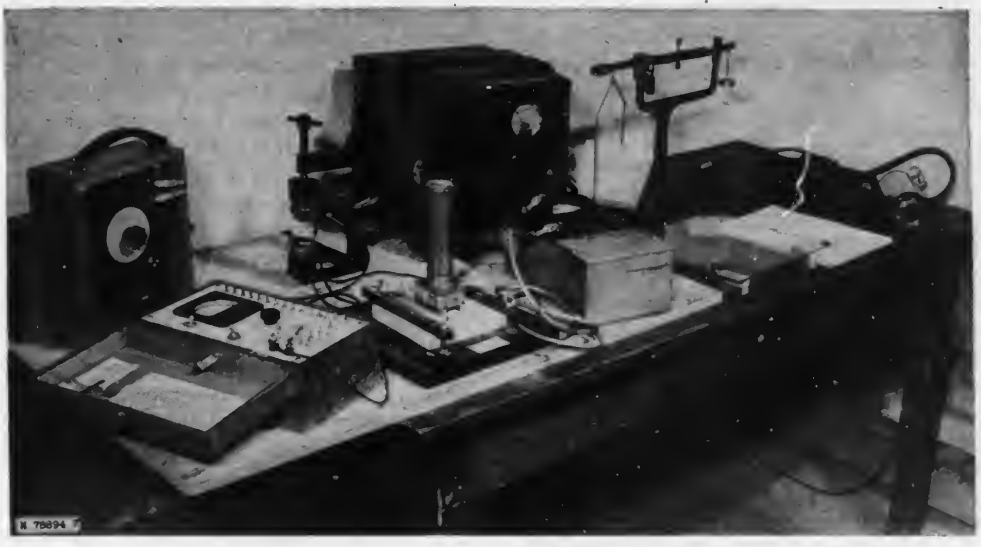


Fig. 1.—Apparatus for weighing and measuring moisture content of samples. Needle contactor is in sample in clamp.

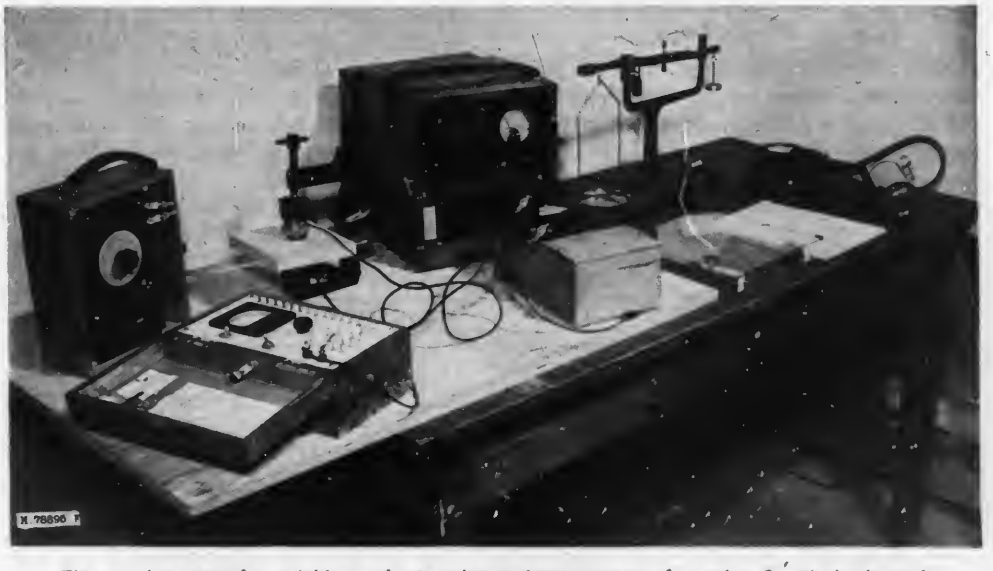


Fig. 2.—Apparatus for weighing and measuring moisture content of samples. Sample is clamped between surface contacts.

of moisture content. Five samples of one species having the same number of plies and the same glue were wrapped in aluminum foil and taken to the 30-percent room. When a sample was removed from the package, it was weighed and its moisture content was taken as quickly as possible with the several meters and electrodes.

After the moisture content of all samples had been determined with moisture meters, it was determined again by the oven-drying method.

Finally, the volume of each sample was determined by a water-displacement method, and the density of the oven-dry samples was computed.

Measuring

Each sample was weighed to the nearest hundredth of a gram. It was placed on the glass sheet, and its moisture content was determined with the radio-frequency power-loss meter. It was transferred to the clamp with surface contacts, and the clamp was tightened until the indicated moisture content was independent of pressure. Leads from the contactor were connected successively to the four resistance meters, and the moisture-content indication of each meter was recorded. The sample was transferred to the clamp for the needlepoint electrodes, and the moisture content was recorded for each meter. All samples were replaced on the conditioning rack until they were oven-dried.

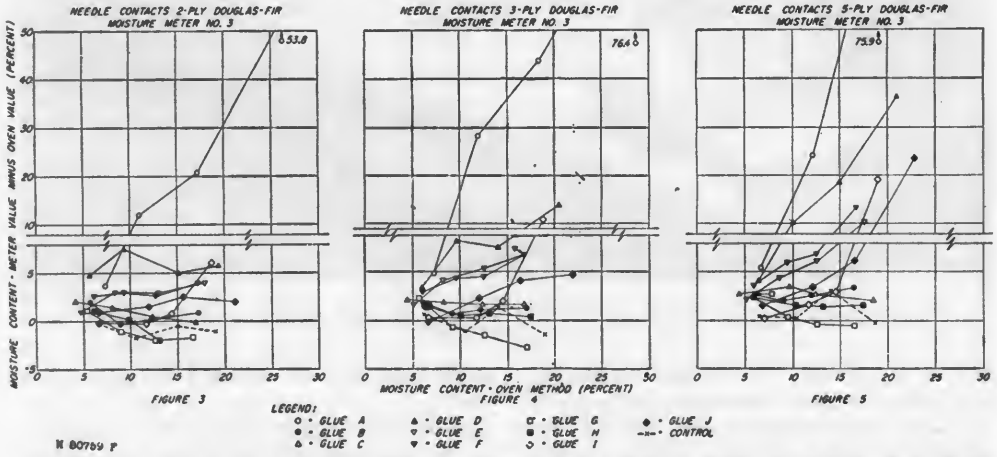
Data and Discussion for Douglas-Fir Plywood

With a few exceptions, the values of moisture content obtained for any number of plies and any glue were the averages of five values obtained from five test samples. The exceptions occurred when the moisture content was beyond the range of one or more of the moisture meters. Although meters Nos. 1, 2, and 4 covered practically the same range of moisture content, meters Nos. 1 and 2 would not indicate values of moisture content that were just within the range of No. 4 and within the marked range of Nos. 1 and 2. Because of this situation, which is not understood, and because of the resulting dearth of data, meters Nos. 1 and 2 have been omitted from the discussion.

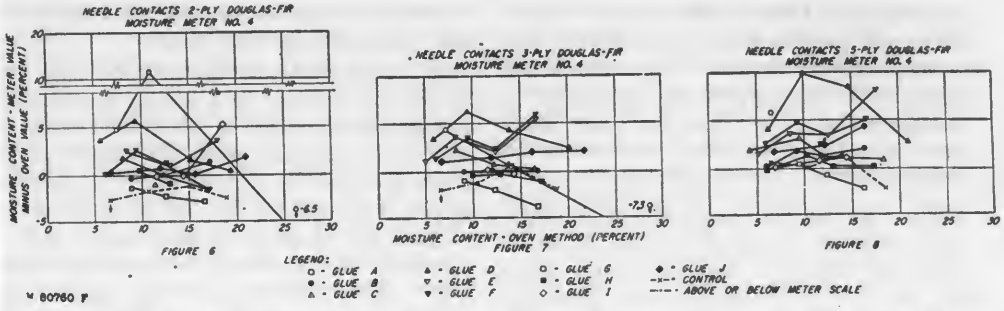
Controls were untreated veneers that were clamped together at the time when their moisture content was measured with the moisture meters. Two sheets were clamped together for each two-ply control, three sheets for each three-ply control and five sheets for each five-ply control. Each sheet of veneer was used only once as a control. The veneers were 1/16 by 5 by 5 inches and had received the same conditioning as the plywood.

The curves of Figs. 3 to 17 show the differences between meter indications and moisture content determined by oven-drying for two resistance types (Nos. 3 and 4) and one radio-frequency power-loss type (No. 5) of moisture meter for all glues with both needle and surface contacts. Differences between meter and oven-dry values are plotted vertically against oven-dry values horizontally. The differences represent the errors in moisture content as determined by the meters.

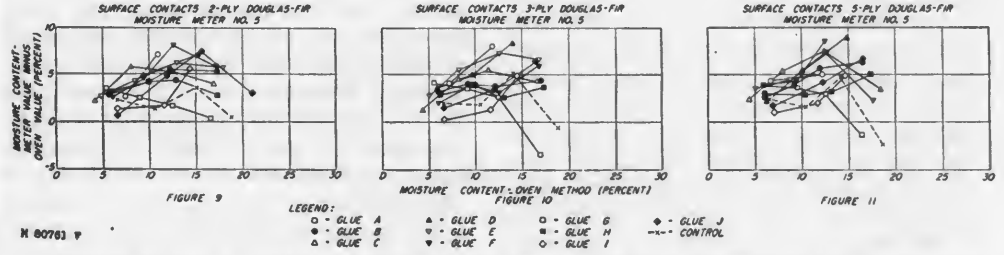
These curves show that moisture-meter errors tend to become greater as the number of glue



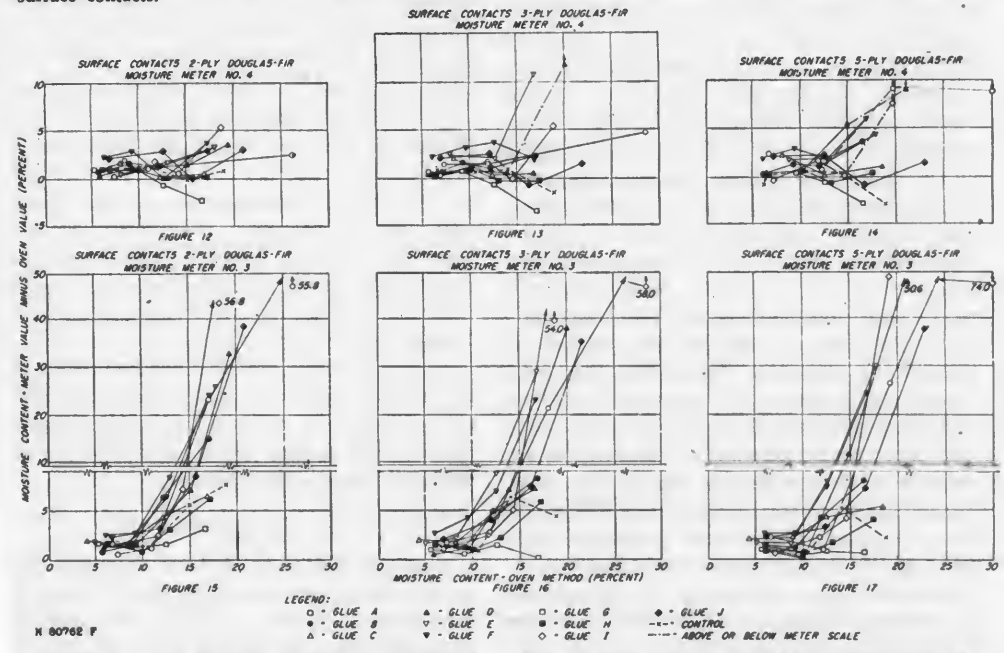
Figs. 3, 4, and 5.—Differences between moisture content of plywood determined with moisture meter No. 3 and by oven-drying for 10 glues and one control at several values of true moisture content using needle contacts.



Figs. 6, 7, and 8.—Differences between moisture content of plywood determined with moisture meter No. 4 and by oven-drying for 10 glues and one control at several values of true moisture content using needle contacts.



Figs. 9, 10, and 11.—Differences between moisture content of plywood determined with moisture meter No. 5 and by oven-drying for 10 glues and one control at several values of true moisture content using surface contacts.



Figs. 12, 13, 14, 15, 16, and 17.—Differences between moisture content of plywood determined with moisture meters No. 4 (Figs. 12, 13, 14) and No. 3 (Figs. 15, 16, 17) and by oven-drying for 10 glues and one control at several values of true moisture content using surface contacts.

lines increases. There is only a trend of meters Nos. 4 and 5 in this direction, but meter No. 3 shows a very pronounced effect for most of the glues. Furthermore, within the same range of moisture-content values meter No. 3 had larger errors than No. 4, and there seems to be no direct explanation for the difference.

The radio-frequency power-loss meter No. 5 might be expected to differ from the resistance type because it depends on the high-frequency dielectric properties of the wood and not on the direct-current resistance of the wood. However, its behavior was similar to that of No. 4.

The range of errors due to the glue lines was quite different for the three meters reported. Meter No. 3 showed errors from 0.0 percent to an indeterminate value above 100 percent in moisture content with needle contacts and up to 74 percent with surface contacts. The range for meter No. 4 was from 0.0 percent to a value judged by the behavior of the meter to be far beyond its upper limit for both needle and surface contacts. The lowest error for meter No. 5 was 0.3 percent, and again the largest error was too large to be determined. The very large errors cited are principally for glue A, and although many of the errors due to other glues were large, it was usually possible to get a moisture-content measurement within the limits of the meters' scales.

The dashed line on Figs. 3 to 17 is the curve of moisture-meter error when used on the unglued controls. Although this error is surprisingly large in some cases, the presence of most glues results in much greater errors with both needle and surface electrodes. The large positive errors are most probably due to electrolytes in the glues that diffuse into the wood during the pressing and heating operations and during subsequent conditioning. The electrolytes become conductors in the presence of moisture, and their conductance increases with the moisture content of the wood within the range of these experiments, probably much more rapidly than does the conductance of normal wood. This is shown by the high values of moisture content of the plywoods as compared with the unglued veneers in the controls. The reasons why moisture-meter values sometimes were lower than oven-dry values and why the curves of glue G drop with increasing moisture content are not understood.

It is apparent from the curves that very little confidence should be placed in the accuracy of the moisture content of plywood when measured with a moisture meter. The magnitude of errors involved will depend upon the number of glue lines, both the type and particular batch of glue, and the actual moisture content of the plywood. Probable variations in the composition of different batches of any single glue may be large enough to displace the corresponding error curve in any of Figs. 3 to 17 a significant amount. Furthermore, it is probable that the user of a moisture meter would not have accurate knowledge of the glue used in the plywood on which he might wish to use the meter. With this array of variables to cause errors in moisture-meter indications of moisture content of plywood, it would be hazardous to place much confidence in such measurements.

Moisture meters can be used on plywood to show moisture-content differences between various points on a single sheet of plywood or between different sheets made under the same conditions with one batch of glue, provided the glue is kept well mixed. Such values would be only relative with respect to each other, but generally would not be correct in magnitude.

The dielectric properties of plywood are influenced by the same factors that determine the direct-current electrical resistance of plywood, but it would not be expected that the dependence would be the same for the two cases. It is interesting to note, however, that glues that caused large errors with resistance-type meters generally caused large errors with the radio-frequency power-loss meters.

Errors in moisture-meter determinations of the moisture content of yellow birch plywood, not discussed in this paper, were generally greater than errors found in measurements made on Douglas-fir plywood.

Conclusion

It is generally to be expected that the moisture content of plywood determined with moisture meters will be unreliable and probably too high. The magnitude of the error will depend upon the particular glue used in the plywood and its moisture content. The error

will depend not only on the type of meter—resistance or radio-frequency power-loss—but also appears to be different for resistance meters made by different manufacturers. Errors that increase with the moisture content of the wood are probably caused by the electrolytes introduced by the glue that become conductors when in contact with moisture in the wood.

Plywood manufacturers may be able to calibrate moisture meters for use in their own plants by comparing moisture meter values with oven-dry values for the various combinations of glue and species of veneer used in the plywood. Meters may even have sufficient accuracy without corrections for certain glue and species combinations unless very accurate values are required. A fabricator using plywood, however, may not know, indeed probably would not often know, the glue composition used in his plywood, and therefore would have no basis for applying any particular correction to his moisture meter indications. Such an operator should not rely on a moisture meter to yield the correct moisture content of his plywood. The distribution of moisture in a sheet of plywood can be ascertained with a moisture meter, and relative values of moisture content of plywood sheets that were made at one time with the same glue can be determined with a moisture meter, but such values may not be very close to the actual moisture content of any sheet.

Discussion

Harry Hull St. Clair (Hart Moisture Gauges, Inc.): Manufacturers of moisture meters evidently were not consulted or asked for helpful suggestions before the tests were made. As it was, the contacting methods used doomed the tests to failure.

In the first place, many adhesives are purposely made more electrically conductive than wood, for bonding with high-frequency currents, and so there was no reason to believe that bare electrodes could be used to pierce both the wood and the highly conductive glue lines without the latter enormously increasing the meter reading. Plywood can be tested to the core with electrodes so insulated that the intervening adhesive films do not appreciably increase the meter reading. This reading can in turn be compared with surface readings of each face of the plywood made with a proper type of surface contactor. I will admit that when no layer is thicker than 1/16-inch, as in the samples used, it would be very difficult and expensive to devise suitable pointed electrodes insulated in such manner as to insure uniformity of contact, but this would not be as difficult to do in the case of plywood which has at least one layer thicker than 1/16-inch.

The needlepoint contactor used with meters Nos. 3 and 4 was never designed for testing total thicknesses as small as 2/16 to 5/16-inch; and even if used on unglued wood of such thicknesses, considerable correction would have to be made for the reduction of electrical field and contact.

In the next place, there was error in assuming that the same needlepoint contactor could be used with both meters Nos. 3 and 4 without corrections for differences. The contactors of the two meters are not the same. One of them will pass about 2.8 times as much current as the other contactor, when used to test unglued wood of not less than ¾-inch thickness, and so, when used with the same meter, it will indicate about 7.65 as compared with 7 percent, 24 as compared with 20.73 percent, and there will be very much greater differences at higher moisture levels. When used to test unglued wood of only 2/16-inch thickness, it will pass about 6.4 times as much as the reduced current passed by the other contactor when applied to the same thickness, with consequently much greater differences in moisture indication. As a matter of fact, the calibrations of the two meters are not the same throughout their respective ranges.

Furthermore, the surface-contact tests were improperly made by tightening the clamp until the indicated moisture was apparently independent of pressure. This involves a personal factor, lack of uniformity and considerable chance of error, particularly as the wood becomes more compressible with higher moisture. Whatever form of surface contact is used, there must be uniform contact and pressure.

I believe that faulty contacting was only partially responsible for the results. Something must have interfered with proper operation of meter No. 3 and possibly of No. 4, as seems to be obvious from Figures 12–17, containing only curves of surface tests. In each case the

sample was presumably under the same pressure when connected to each meter. Differences between calibrations of the two meters cannot possibly account for the wide variations between their responses. Perhaps the multiplicity of connections and wires may have been a contributing cause. Indeed it would appear to me from the photographs of the apparatus that the two meters were probably in some way interconnected and affecting each other. At any rate, these differences definitely point to serious interference with the operation of the meters even when the piercing of glue lines was not involved; and it would seem that the inferences from Figures 12–17 are sufficient warrant for belief that the results of needlepoint tests were vitiated by the same causes. Under the circumstances I do not believe that the figures report anything like the results which would have been obtained if errors of method and faults in use and connections had been carefully investigated and corrected.

Mr. Bell: Since electrical moisture meters as supplied by the makers are used to measure the moisture content of plywood, the tests were conducted in practically the same manner as measurements would be made in woodworking establishments. This meant using normal needlepoint electrodes that would yield data comparable with what would be obtained by most meter operators. The use of special contacting methods would have defeated the purpose of the texts.

The glues, except A, were typical of types found in plywood made by hot and cold press methods and were not formulated to have high electrical conductivities for setting with dielectric heating.

As noted in the comments, insulated electrodes could be used on plywood with laminations sufficiently thick that the field between electrodes would not be affected appreciably by the nearest glue line but would not help with 1/16-inch laminations. Five-sixteenths-inch needles are not intended for use on material less than 5/16 inch, but they were used on thinner material to find the errors resulting from such use when no correction was made for thickness.

The needlepoint contactor was nearly the same as that supplied for one of the meters Nos. 3 and 4. The differences between the moisture content values determined by meters Nos. 3 and 4 using the selected contactor were 0.2 percent at both 7 and 11.5 percent moisture content. Higher and lower values were not checked, but greater differences might be expected particularly at high values of moisture content.

Results with surface contactors are comparable on the basis of the largest pressure applied because the independence of moisture content and pressure should have permitted all pressures to have been increased to the largest value with no change of indicated moisture content.

No satisfactory explanation for the difference in behavior of meters Nos. 3 and 4 as shown by the curves of figures 12–17 has been developed. All corresponding points were determined with no change in physical or electrical conditions of the sample. Each sample when under pressure between the electrodes was not disturbed until its moisture content had been measured with all meters. Many of the points in the high moisture content region were checked several times to establish the values definitely. A single lead from the contactors that was connected directly to only one isolated meter at one time precluded the possibility of interaction between meters.

The curves in this report cannot be used as a basis for comparing the merits of the several meters; they can be interpreted only as a warning to those who use moisture meters on plywood that moisture meter indications of very high moisture content may be quite inaccurate, and that most values will be high by an amount that depends on the glue, the species of wood used, and the actual moisture content of the plywood.

John D. Ritchie (Douglas Fir Plywood Association): It would seem from the charts that the variables developed in readings on sets of unglued veneers were wide enough to throw doubt on the value of moisture meters produced to date aside from the effect of glue lines.

Meters are used in the Douglas fir plywood industry on veneers primarily. We have found that readings are only a general indication.

Moisture meters are desirable because they are easy to use and readings may be obtained at once. Aside from this, the oven-dry method is satisfactory.

Would it be possible to work out a heating unit, possibly high frequency, to boil moisture out rapidly so that an on-the-spot record might be obtained? I realize that, according to the oven-dry method, moisture is taken out at 212° F. in order that only water be removed.

My question is; would it be possible to calibrate a high-frequency heating unit to take care of the natural rosins which might be taken out and wind up with a more accurate measure than present meters, along with speed of operation?

Mr. Bell: A high-frequency dielectric heating unit designed to heat wood samples of a certain size and remove the moisture for moisture content determinations appeared on the American market somewhat over two years ago. The heating time advertised was about 3.5 minutes. No calibration was provided to correct for extractives other than water, and such a calibration for the type of apparatus cited would be difficult if not impossible to make.

Alan A. Marra (Webster, New York): You mentioned the possibility that a particular meter might be calibrated to give comparable data with a certain glue formulation. Would not the readings be affected by the amount of glue spread as well as by the type of glue used?

Mr. Bell: The relation between thickness of glue line and effect on moisture meter indication cannot be determined from our measurements. However, a thick glue line would be expected to act as a conductor of large cross section as compared with a thin glue line and consequently have a greater effect on a meter indication. Portions of the glue that would diffuse into the wood during a gluing operation would also affect a moisture meter indication, and therefore there probably is no simple relation between thickness of glue line and accuracy of meter indication. The glue lines in commercial plywood probably would be sufficiently uniform that the variations would not be important. However, this point should be verified experimentally if a moisture meter is to be used on plywood. If a moisture meter is calibrated for use on plywood made with a particular glue and species, the calibration should be checked frequently against values obtained by oven drying to detect any effects of unnoticed variations in material or procedure.

E. George Stern (Virginia Polytechnic Institute): Can you give comparative data on the accuracy of the instruments for solid wood?

Mr. Bell: The accuracy of most moisture meters when used on solid wood 3/4 inch or more in thickness is about the same. When a moisture meter is used with a knowledge of its limitations as well as its capabilities the accuracy of moisture content determinations should be within 1 percent of moisture content.

In Figures 3 to 8 the curves for the controls shows that when needle contactors are used on thin material the indicated moisture content will probably be below the oven dry value.

B. C. Christeson (Anderson Coach Company): How would you advise measuring moisture content of plywood and what could be used as a standard?

Mr. Bell: The standard oven-drying procedure is probably the best method for determining the moisture content of plywood, although it is not fast. The distillation method has about the same accuracy and requires less time, but the apparatus probably would not be found in many plants making or using plywood. Moisture meters can be used on plywood, but the conditions noted in paragraph 2 of "Conclusions" and in the reply to Mr. Marra's question should be observed.

The Utility of No. 3 Common Northern Hardwood Lumber for Mechanized Processing Into Glued Products

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The utility of low grade lumber for a given use is dependent upon the amount, size, and character of the useable portions, and upon development of economic methods of converting this material into the desired products. Mechanized processing, both in recovery of the useable material and product fabrication is essential to full realization from the grade of No. 3 Common northern hardwood lumber. Present day mechanization together with modern gluing techniques offer possibilities for development of superior wood products from this grade of lumber.

Introduction

Purpose of Study

THE lumber industry in northern Michigan is concerned about the poor marketability of low grade lumber. Although the demand for low grade lumber during World War II often exceeded the supply due to heavy requirements for packaging and crating material, it is apparent that this was an abnormal situation. The present status in which upper grades are in good demand and lower grades are in excess of demand reflects a more normal condition of the lumber market. Recognizing that a turn towards normality would bring with it certain marketing problems, the Advisory Committee to the Forest Products Research Division of Michigan College of Mining and Technology gave high priority to this research project on utilization of low grade northern hardwood lumber. The problem, however, is of more than local or regional interest and the results obtained to date in this study may perhaps offer a suggestion for further investigations following this approach.

Low grade hardwood lumber is differentiated from upper grade lumber chiefly on the basis of size, character (as clear or sound), and percentage of material recoverable from the individual board. Except where either the heartwood or sapwood is preferred on account of some peculiarity such as color, the clear portion of a low grade board is technically equivalent in properties to the same size portion from an upper grade board. Despite this technical equality, the lower grades of hardwood lumber have found wide-spread use only in products where little or no value can be placed upon the quality of the clear portions alone. The generally accepted reason for this situation is attributed to the low recovery in clear material from low grade lumber and consequent high cost which precludes its use in the average manufacturing plant. An added consideration is the higher cost of processing small cuttings.

That this condition holds for conventional and time-honored methods of processing there can be little doubt. Developments in mechanized processing and gluing techniques seem to offer new possibilities for utilization of the smaller high grade portions of low grade lumber. The objective of this research project is to increase the utilization value of low grade northern hardwood lumber to the producer and consumer by development and application of new methods of converting this grade of lumber into marketable products at or near the point of milling.

In this project the problem grades and species were studied to determine new possibilities of use in the full board and as cuttings. The new procedure included the examination in detail of adequate samples of No. 3A and 3B Common hardwood lumber[1] of the principal northern species according to defect classes which would limit it for specific uses. The recovery in useable cuttings of several uniform sizes was measured. Work has been initiated

[1] *Rules for the Measurement and Inspection of Hardwood Lumber* by National Hardwood Lumber Association.

on development of economical methods of removing defects and reconstituting the useable portion into products.

Economic Aspect of Problem

Profitable utilization of low grade lumber is a problem that is being forced upon both the producing and consuming industry. The general scope and complexity of this problem can best be illustrated by recalling the frequency and intensity with which it is discussed in technical and trade circles.

Statements that the proportion of low grade lumber to total production is increasing are frequently noted in the lumber trade journals. That this trend is not necessarily of recent origin could no doubt be substantiated, as could also the fact that there is no likelihood of a reversal of this trend in the near future. There are several economically sound reasons why the proportion of low grade lumber is increasing: (1) an increasing percentage of the higher grade logs now go into veneer, (2) closer utilization of the stand is being effected, including top and defective logs, (3) in some instances poorer timber stands are being logged, (4) more second growth timber is being cut, and (5) utilization of many previously rejected species has brought to market lumber of lower grade due to small size or physical characteristics of the species. In northern hardwoods such as those typified by operations in the Upper Peninsula of Michigan, the grades of No. 3A and 3B Common may now constitute from 30 to 50 percent of an average mill's production (Table 1). For the year 1946 this was equivalent to approximately 100 million board feet. It will be recognized that this volume of low grade might well constitute a major utilization problem.

Suggested solutions for this problem have usually involved endeavors to expand markets for low grade uses such as blocking and dunnage, mine lumber and ties, railroad ties, etc., or fabrication of products where low grade lumber is acceptable as in pallets, crating, coal and grain doors, etc. These and similar uses have traditionally furnished the market outlet for low grade lumber except for such portions of No. 3A Common that have always gone into flooring, particularly in hard maple. In order to test this grade of lumber for all possible uses, a classification has been outlined into which each low grade board could be tentatively placed as a result of the green lumber inspection. The following is a description of the use classes into which boards were separated based on defects in this study:

Use Class 1 (Cutting Class)

This classification will take all boards having defects of such nature that they must be eliminated before the acceptable material in the board can be used. Characteristic defects are large knots or holes, splits, shake, rot, and wane, or any combination of these defects that are limiting.

Use Class 2 (Construction Class)

This classification is designed to take boards having defects of such nature that the piece can be used in its entirety without undue cutting or wastage. Characteristic defects are tight knots, pin and shot worm holes, wane, splits, checks, stain, and pith.

Use Class 3 (Finish Class)

This classification is intended to take boards having numerous small sound defects of such nature that value may be added to the piece by reason of these defects for such use as figured panelling, interior trim, or special millwork. This classification is characterized by small tight knots, light stain, burls, pinworm holes, birdseye, and defects of this character.

Most traditional uses for low grade northern hardwoods are those which are shared with woods of inferior technical qualities of the

TABLE 1.—GRADE RECOVERY FOR CERTAIN SPECIES OF NORTHERN HARDWOODS[1]

Species	No. 1 Common and Better	No. 2 Common	No. 3 Common	Total
	Percent			
Hard maple	39.6	24.5	35.9	100.0
Yellow birch	44.9	24.7	30.4	100.0
Soft maple	34.2	31.3	34.5	100.0
Beech	17.5	31.3	51.2	100.0

[1]Basis 79,302 bd. ft.

clear wood. The defects in No. 3 Common hardwood boards place all species in the same price range and create an advantage for those species produced nearest the market or in areas of lower production cost, regardless of the utility of the clear wood.

The ready marketability and relatively high price of the better grades of the principal species of northern hardwood lumber leaves little doubt as to the preferred position of these woods from the standpoint of the technical qualities of the woods themselves. Opportunity for the enlargement of the market for low grade lumber therefore, seemed to lie principally in those uses that require wood of the same high technical quality either in sizes that could be produced economically from low grade or by fabrication of the required sizes by gluing. The new look at the problem, as detailed in this study, proposes processing of low grade lumber to secure the maximum amount of high grade material for fabrication of high grade products by the most economical methods that can be devised.

Method

Collection of Samples

The grades of lumber studied were No. 3A and 3B Common, nominal 4/4 thickness. The principal species examined were hard maple, *Acer saccharum,* yellow birch, *Betula lutea,* soft maple, *Acer rubrum,* and beech, *Fagus grandifolia.* Lumber samples were collected from three locations situated geographically to obtain a cross-section of the general areas of old growth northern hardwood type.

Each lumber sample was collected at an operating sawmill. All logs sawed during the collection of the sample were tallied by species, log grade (under Northern Hemlock and Hardwood Association grading rules), diameter, length, and scale for possible correlation with lumber yields. All lumber sawed during the test period was graded and tallied on the green chain by a qualified inspector according to National Hardwood Lumber Association rules. Usual sawing and mill practices were unvaried except that the sawyer was instructed to saw as much as possible of the No. 3 Common in 4/4 thickness. All 4/4 No. 3 Common boards were marked as to species and grade by the inspector. Each board so marked was then examined and recorded as to species, grade, width, length, use class, and the type of defect most responsible for its low grade character.

A total of 2,740 boards, or 16,260 bd. ft. of No. 3 Common lumber were thus examined. A net sample of 548 boards, or 3,346 bd. ft. was obtained for further study by selecting every fifth No. 3 Common board regardless of species, size, grade, or any pre-determined characteristic, and numbered consecutively. The net sample volume thus obtained was 20.6 percent of the gross volume examined with the highest volume percentage deviation in the principal single species of 24.8 percent for yellow birch No. 3A Common (Table 2).

The greatest deviation in use classes from the theoretical 20 percent net sample volume occurred in use class 3 with a net volume of 24.7 percent of the gross. This use class represented only 5.0 percent, however, of the total net sample volume (Table 3).

TABLE 2.—COMPARISON OF VOLUME IN GROSS AND NET SAMPLES BY SPECIES AND LUMBER GRADE

Species	No. 3A Common			No. 3B Common			Total net as a percent of gross
	Gross sample	Net sample	Net as to gross	Gross sample	Net sample	Net as to gross	
	Board Feet		Percent	Board Feet		Percent	Percent
Hard maple	4174	857	20.5	4019	783	19.5	20.1
Yellow birch	1030	255	24.8	956	195	20.4	22.6
Soft maple	885	180	20.3	533	121	22.7	21.2
Beech	2988	567	19.0	1179	272	23.1	20.1
Other	145	47	32.4	351	69	19.7	23.4
All species	9222	1906	20.7	7038	1440	20.5	20.6

TABLE 3.—COMPARISON OF VOLUME IN GROSS AND NET LUMBER SAMPLES BY USE CLASSES

Use Class	Gross sample		Net sample		Net as to gross
	Board Feet	Percent	Board Feet	Percent	Percent
1	12,389	76.2	2404	71.8	19.4
2	3,198	19.7	776	23.2	24.3
3	673	4.1	166	5.0	24.7
Total	16,260	100.0	3346	100.0	

TABLE 4.—COMPARISON OF BOARDS IN GROSS AND NET SAMPLES BY DEFECT CLASSES

Defect class	Gross sample		Net sample		Net as to gross
	Boards	Percent	Boards	Percent	Percent
Large knots	822	30.0	166	30.3	20.2
Medium knots	385	14.0	77	14.1	20.0
Small knots	129	4.7	33	6.0	25.6
Shake	673	24.6	131	23.9	19.5
Wane, bark	582	21.2	114	20.8	19.6
Rot, doze, stain	149	5.5	27	4.9	18.1
Total	2740	100.0	548	100.0	

A comparison of boards by defect classes in the net as a percent of the gross sample shows good correlation except in the case of small knots which was represented by 25.6 percent in the net sample (Table 4).

These data show that the net sample of 3,346 bd. ft. is a fair representation of the gross sample of 16,260 bd. ft., and of the 4/4 No. 3 Common lumber produced during collection of the sample.

An analysis was made of the grade tally of all lumber sawed during collection of the samples. The results indicate that a representative sample based on the percentage of occurrence of species by volume in the old growth northern hardwood type was secured as shown by the comparison in Table 5. It was concluded, therefore, that the total net sample of 548 boards of No. 3 Common northern hardwood lumber is representative of the type in which it occurs, and that measurements made from such a sample are generally applicable to this grade.

TABLE 5.—COMPARISON OF THE COMPOSITION OF THE OLD GROWTH NORTHERN HARDWOOD TYPE[2] WITH THE LUMBER SAWED DURING COLLECTION OF THE STUDY SAMPLE

Species	Old growth type	Lumber sawed during test
	Percent	Percent
Hard maple	51.8	50.5
Yellow birch	22.6	22.6
Soft maple	5.7	7.9
Beech	9.0	12.2
Other[1]	10.9	6.8
Total	100.0	100.0

[1] Basswood, Elm, Oak, and Ash.

Examination and Measurement

The lumber samples to be measured were kiln dried as lumber green from the saw and surfaced two sides for convenience of working and study, with grade markings and numbers re-established after surfacing. Each board was then re-examined as to lumber grade, width, length, use class, and type of defect now judged to be most responsible for its low grade character. The effect of kiln drying was particularly noted in the assignment of use and defect classes. Each board in half of the total net sample (274 boards) was examined and measured for the amount of useable material in clear 1 face and paint grade cuttings[3] in each of the following fifteen sizes:

1 in. by 1 in. by 8 in.—12 in.—16 in.—20 in.—random length,
1 in. by 2 in. by 8 in.—12 in.—16 in.—20 in.—random length,
1 in. by 3 in. by 8 in.—12 in.—16 in.—20 in.—random length.

The balance of the total net sample (274 boards) was handled on the same basis except that each board was measured in only nine sizes, the 12 and 20 inch cutting lengths being eliminated. Measurements were recorded in units (12 sq. in. or 1/12 bd. ft.). Measurement was made by means of a transparent grid on which the size of cutting was blocked out with lines representing the saw kerf required to rip and cross-cut a given size cutting.

Cutting Test

The method of examination and measurement used in this study has the very desirable feature of allowing the same board to be measured for recoveries in the several sizes and grades of cuttings to provide direct comparison of results. It also allows real economy in the amount of lumber required in order to secure comparable statistical accuracy. In the final analysis, however, the acid test of recovery percent in a given size cutting can only be

[2] Revised Forest Statistics for the Lake States, Station Paper No. 1 The Forest Survey, Lake States Forest Experiment Station. 1945.

[3] *Commercial Standard CS60–48 for Hardwood Dimension Lumber* by U. S. Department of Commerce, National Bureau of Standards.

made on the basis of what transpires when a board is actually ripped and crosscut and tallied in a specific size and grade.

An actual cutting test was made on a random sample drawn from one unit of 177 No. 3 Common boards. Beech was the only major species not represented in the random sample. The test was made in the 15 cutting sizes enumerated previously, using five boards in each size class. The recovered material was classified as clear, clear 1 face, and paint grade cuttings. The fall-down was computed as to percent useable without differentiation as to size or grade of cutting. The minimum size tallied was a piece 1 by 1 by 8 inches.

Results

Defect and Use Class Examination

A comparison was made to show the type of defect most responsible for the grade of No. 3A and No. 3B Common northern hardwood boards; also the effect of kiln drying and surfacing on the assignment of these same defects (Table 6). Knot defects are the principal assigned reason for the grade of the board in No. 3A Common in both the green and kiln dried condition with approximately 60 percent of the cases falling in this category. Defects other than knots, such as shake, wane, and rot, are the principal assigned reason in No. 3B Common in both green and kiln dried conditions. With the exception of small and medium knots these are types of defects that ordinarily have to be eliminated before the board can be used for high grade purposes. Splits and shake which might be expected to increase in kiln drying were actually reduced by three percent in each grade of lumber. Surfacing after kiln drying does aid in determining the most prominent defect in each board.

TABLE 6.—COMPARISON OF EFFECTS OF KILN DRYING ON ASSIGNMENT OF DEFECTS BY GRADES OF LUMBER

Defect	No. 3A Common		No. 3B Common	
	Rough green	K. D. S2S	Rough green	K. D. S2S
	Percent		Percent	
Large knots[1]	34	44	26	36
Medium knots[2]	19	14	7	6
Small knots[3]	7	3	3	0
Splits and shake	16	13	35	32
Wane or bark	22	25	20	20
Rot, doze, stain	2	1	9	6
Total	100	100	100	100

[1]Knots 1¼ in. or larger in diameter.
[2]Knots larger than ⅝ in. but less than 1¼ in. in diameter.
[3]Knots less than ⅝ in. in diameter.

The preceding comparison is closely related to the percentage of the lumber volume that develops by use classes in No. 3A and 3B Common as the result of kiln drying (Table 7). No significant change occurs in use classes between green and kiln dried condition in No. 3A Common. However, there is a decided change in the No. 3B Common wherein 91 percent of the total volume falls into use class 1. The bulk of No. 3 Common lumber, regardless of grade, falls into use class 1 which is the cutting class. The relatively small proportion of the total volume represented in use classes 2 and 3 makes it impractical to segregate it for special processing and uses. It is evident that all of the lumber must be cut and further processed in order to give full utility for high grade products.

TABLE 7.—EFFECT OF KILN DRYING ON USE CLASS VOLUME IN GRADES NO. 3A AND NO. 3B COMMON NORTHERN HARDWOOD LUMBER

Use class	No. 3A Common		No. 3B Common	
	Rough green	K. D. S2S	Rough green	K. D. S2S
	Percent by Volume			
1	73	73	71	91
2	22	20	24	8
3	5	7	5	1
Total	100	100	100	100

Measured Cutting Recovery

The measured recovery from No. 3 Common northern hardwood lumber in clear one face and paint grade cuttings for the nine sizes examined varied from a low of 31.6 percent in the 1 by 3 by 16 inch size to a high of 70.5 percent in the 1 by 1 by random size (Table 8).

TABLE 8.—MEASURED RECOVERY FROM NO. 3 COMMON NORTHERN HARDWOOD (ALL SPECIES) LUMBER BY GRADE AND SIZE OF CUTTING

Size of Cutting	Grade of cutting		Total clear one face and paint
	Clear one face	Paint	
	Percent		Percent
1 by 1 by random	63.1	7.4	70.5
1 by 1 by 8	51.2	10.6	61.8
1 by 1 by 16	38.5	13.6	52.1
1 by 2 by random	48.3	9.5	57.8
1 by 2 by 8	36.4	12.6	49.0
1 by 2 by 16	25.2	14.7	39.9
1 by 3 by random	37.2	9.7	46.9
1 by 3 by 8	26.4	12.5	38.9
1 by 3 by 16	17.1	14.5	31.6

The random length cutting in each width class shows a higher percent of recoverable material than either of the uniform lengths. The effect of length in the uniform sizes is indicated by the decrease in recovery percent with increase in length of cutting. These decreases are 9.7 percent from the 8 to 16 inch length in the 1 inch width, 8.1 percent in the 2 inch width, and 7.3 percent in the 3 inch width.

TABLE 9.—MEASURED RECOVERY FROM NO. 3A AND 3B COMMON HARD MAPLE LUMBER BY GRADE AND SIZE OF CUTTING

Cutting size	No. 3A Common			No. 3B Common		
	Clear one face	Paint	Total clear one face and paint	Clear one face	Paint	Total clear one face and paint
		Percent			Percent	
1 by 1 by random	66.3	8.4	74.7	54.1	9.0	63.1
1 by 1 by 8	53.3	12.7	66.0	39.3	13.6	52.9
1 by 1 by 16	41.2	16.1	57.3	29.4	16.3	45.7
1 by 2 by random	51.8	10.2	62.0	38.3	11.1	49.4
1 by 2 by 8	38.1	14.6	52.7	27.0	14.8	41.8
1 by 2 by 16	26.9	17.9	44.8	17.3	16.2	33.5
1 by 3 by random	40.5	11.0	51.5	27.6	11.7	39.3
1 by 3 by 8	28.6	16.3	44.9	17.6	14.2	31.8
1 by 3 by 16	18.7	18.1	36.8	9.2	15.0	24.2

The effect of species and grade on recovery percent are shown in Table 9 for No. 3A and 3B Common hard maple lumber. The mean of recovery percentage for any cutting size in either grade has an accuracy of at least plus or minus 4.4 percent.[4] Hard maple is the only species of the four that were studied that is represented by a sufficient number of boards in both No. 3A and 3B Common to provide the statistical accuracy desired.

Measurements plotted in graphical form for convenience of reference may frequently be of use to determine relationships, if any exist, between points whose coordinates satisfy a given equation, and frequently for interpolation between observed values. An analysis of the plotted recovery percentages for the 274 boards in the 8, 12, 16, and 20 inch lengths for each width class gave strong indications that in the uniform cutting sizes within this range the percentage of recoverable material is a function of length of cutting and that this relationship can be expressed as a straight line corresponding to the equation:

$$R = \frac{L - a}{b}$$

in which

L = Length of cutting
R = Percent of recoverable material
a and b = Constants

This equation permits calculation of percentage recoveries for any length of cutting between 8 and 20 inches from data for any two determined values. These data for 8 and 16 inch lengths are set forth in Tables 8 and 9.

The relationship between percentage recovery and width of cutting deviates slightly from

[4] Standard deviation of the mean is 1.46 percent. In 99.7 cases in 100 the means from other comparable data will fall within 4.4 percent of this mean.

TABLE 10.—COMPARISON OF RECOVERY FROM MEASUREMENT[1] AND ACTUAL CUTTING TEST BY SIZE AND GRADE OF CUTTING

Length of cutting	1 in. Width		2 in. Width		3 in. Width	
	Measured	Cut-up	Measured	Cut-up	Measured	Cut-up
	Percent		Percent		Percent	
In Paint Grade and Better Cuttings						
Random	55	54	49	50	44	45
8 inch	57	57	39	40	47	55
12 inch	59	59	45	55	27	36
16 inch	56	57	23	43	33	42
20 inch	46	53	16	31	25	39
In Clear One Face and Better Cuttings						
Random	54	51	40	40	38	43
8 inch	48	52	36	40	36	46
12 inch	41	54	25	39	16	23
16 inch	42	50	10	22	16	25
20 inch	27	41	7	16	2	11

[1] 5 boards in each cutting size, each measured, and later cut-up.

a straight line in each length class. However, practical estimates of recoveries for intermediate width can be made by straight line interpolation between 1 and 2 inches, and 2 and 3 inches.

Actual Cutting Test

The results of this test (Table 11) were somewhat erratic due to the statistical inadequacy of the sample of individual sizes. Further tests of this nature are planned. Some indication can be gained, however, of certain trends by comparison of the actual cutting recovery with the measured recovery from the same boards in the same size cutting (Table 10). The recovery percent from cutting was equal to or greater than the measured in all cutting sizes except in the 1 by 1 by random size and was notably increased in the 2 and 3 inch widths in 12, 16, and 20 inch lengths.

The tendency toward improvement in both yield and grade of cutting when the boards were cut up can be accounted for by the fact that the measurements were made from the poor face of the board, and there was opportunity for improvement when the best face of the actual cutting was considered. The percent recovered in clear cuttings (Table 11) constitutes a substantial proportion of the total recovery of clear one face and better grade cuttings. There are also indications from this test that the total useable material of paint and better grade will be increased substantially, especially in the larger cutting sizes, when the fall-down is taken into consideration.

Application

Comparative Utility of No. 3 Common Northern Hardwood Lumber

The utility of any raw material may be judged on the basis of how satisfactorily it physically serves its intended purpose and whether the cost is competitive with other raw material that will serve the purpose equally well. The concept upon which this research project is based takes into account the necessity of low grade lumber competing economically with the better grades of lumber for given product purposes. In order to compete economically low grade lumber must of necessity have some price differential in its favor to start with. This situation, of course, has existed traditionally in the lumber market and no doubt will continue. The question of economic competition therefore, may be judged in the final analysis on whether the cost of recoverable material in low grade lumber plus the cost of mechanized preparation and fabrication into the desired product is equal to or less than the cost from a better grade of lumber processed by conventional methods.

In the milling procedure certain operations are common to good practice in preparation of stock for gluing and should be charged on a gross footage basis. The cost of raw material plus preparation varies inversely as the net yield of the lumber, i.e. as the yield decreases

TABLE 11.—RECOVERY FROM ACTUAL CUTTING TEST BY SIZE AND GRADE OF CUTTING
(5 boards in each cutting size)

Size of cutting	Entirely clear	Clear one face	Paint	Total paint and better	Fall-down[1]	Total useable
			Percent by Volume			
1 by 1 by random	48	3	3	54	0	54
1 by 1 by 8	43	9	5	57	0	57
1 by 1 by 12	35	19	5	59	5	64
1 by 1 by 16	39	11	7	57	10	67
1 by 1 by 20	21	20	12	53	10	63
1 by 2 by random	28	12	10	50	13	63
1 by 2 by 8	34	6	0	40	16	56
1 by 2 by 12	27	12	16	55	20	75
1 by 2 by 16	9	13	21	43	22	65
1 by 2 by 20	12	4	15	31	26	57
1 by 3 by random	32	10	3	45	36	81
1 by 3 by 8	38	8	9	55	17	72
1 by 3 by 12	13	10	13	36	35	71
1 by 3 by 16	13	12	17	42	25	67
1 by 3 by 20	5	6	28	39	35	74

[1]Paint and better grade cuttings of various sizes to 1 by 1 by 8 inch minimum.

the cost increases in a mathematic ratio. This can be expressed as:

$$C = \frac{M + P}{R}$$

in which,

C = Net cost of material and preparation
M = Gross cost of material
P = Gross preparation costs
R = Percent of recovered material

In order to maintain a limiting net cost of prepared material, lumber with a reduced recovery percent may be used if at the same time gross lumber costs and preparation costs can be reduced proportionately.

Illustration of this relationship as it affects the measured yields of uniform cuttings from low grade lumber is shown in Table 12 in which net cost has been computed for various recovery percents and various preparation costs and assuming No. 3 Common hardwood lumber to be available at a cost of $45.00 per M. bd. ft. A net cost of $150.00 has been assumed as a hypothetical economic limit for purposes of illustration and this figure has been included in the table with its corresponding limiting recovery percent.

If preparation costs can be assumed at $30.00 the low grade lumber must yield 50 percent of useable stock, but any cutting size yielding above 50 percent would produce a margin of saving. At the maximum measured recovery obtained in 1 by 1 by random size (70.5 percent), this margin amounts to $43.62. If, however, the cost of processing could be reduced from $30.00 to $20.00 per M. bd. ft. through greater mechanization, this margin would be increased to $57.81 for the 1 by 1 by random size and the minimum yield requirements lowered to 43.3 percent. At 70.5 percent recovery this $10.00 reduction in processing costs is worth $14.19, but at 43.3 percent it is worth $23.21. With processing costs of $30.00 per M. bd. ft. four of the proposed cutting sizes show a margin above the $150.00 net cost of useable material. If processing costs can be decreased to $20.00 then six cutting sizes show a margin above the assumed net cost.

TABLE 12.—EFFECT OF RECOVERY AND PREPARATION COSTS ON THE NET COST OF LUMBER FOR PRODUCT PURPOSES

Size of cutting	Recovery (R)	Lumber cost per M. bd. ft.		Preparation costs per M. bd. ft. of rough lumber (P)				
				$10.00	$20.00	$30.00	$40.00	$50.00
		Gross (M)	Net	Net cost of prepared cuttings, $C = \frac{M+P}{R}$				
	Percent	Dollars		Dollars				
1 by 1 by random	70.5	45.00	63.82	78.01	92.19	106.38	121.25	134.75
	63.3	45.00	71.09	86.88	102.68	118.48	134.28	150.00
1 by 1 by 8	61.8	45.00	72.81	88.99	105.17	121.35	137.54	153.72
1 by 2 by random	57.8	45.00	77.85	95.15	112.45	129.75	147.05	164.35
	56.7	45.00	79.36	97.00	114.63	132.27	150.00	167.54
1 by 1 by 16	52.1	45.00	86.37	105.56	124.76	143.95	163.14	182.34
	50.0	45.00	90.00	110.00	130.00	150.00	170.00	190.00
1 by 2 by 8	49.0	45.00	91.83	112.24	132.65	153.06	173.46	193.87
1 by 3 by random	46.9	45.00	95.94	117.27	138.59	159.91	181.23	202.55
	43.3	45.00	103.92	127.02	150.00	173.21	196.30	219.39
1 by 2 by 16	39.9	45.00	112.78	137.84	162.90	187.96	213.03	238.09
1 by 3 by 8	38.9	45.00	115.68	141.38	167.09	192.80	218.50	244.21
	36.7	45.00	122.61	150.00	177.11	204.35	231.60	258.85
1 by 3 by 16	31.6	45.00	142.40	174.05	205.69	237.34	268.98	300.63

This illustrative discussion has not included the costs of gluing and it is recognized that some elements of gluing costs will vary with size of cutting even though gluing may be assumed to be done on a modern continuous glue press. The cost elements ignored are glue application, laying-up, and glue costs. However, it is believed that the differences between small and conventional cuttings in these elements are small in comparison with the differences involved in preparation by conventional methods.

The key to economic utility of low grade lumber in the method proposed involves

mainly reduction in costs of preparation through mechanized handling. It is expected that specific costs of preparation may be estimated in a later phase of this project.

Preparation of Low Grade Lumber for Glued Products

It is not profitable to process small cuttings with conventional methods because of the high labor costs. However, small cuttings of uniform size are adaptable to mechanization (conveyors, automatic feeding, and off-bearing) often precluded for larger random width and length cuttings. Good practice in conventional dimension preparation requires at least five machine operations (usually each with a feeder and off-bearer) to prepare rough lumber for gluing. Uniform dimensioned stock need require only two manual operations to the point of gluing, (1) cross-cutting lumber to multiple lengths and (2) sorting and culling for uniform lengths, or knot sawing for random length cuttings.

Low grade lumber is generally regarded as presenting more difficult rough milling problems than higher grade lumber. A portion of this difficulty may be due to the greater prevalence of natural defects such as knots, shake, and wane, and some to the usually poorer treatment accorded low grade lumber in piling, seasoning, and storage. In addition to natural defects low grade boards may have excessive wind or twist, bow, crook, and cup. The effects of bow and crook and to some extent wind or twist can be mitigated by judicious cross-cutting of the board. A facing planing is required however, to fully eliminate the latter and produce one flat surface on the board. Cupping can be reduced in wide boards by center ripping. If boards are to feed against a fence in subsequent machine operations, one edge should be straightened or jointed.

A sequence of operations for preparation of uniform cuttings for edge gluing might be as follows: (1) cut-off, (2) facing planer, (3) sizing planer, (4) jointer to straighten one edge, (5) gang rip-saw, (6) gang cut-off saw, (7) sorting and culling for uniform length cuttings, or knot sawing for random length cuttings, (8) glue jointer or sticker, (9) end joining for random length cuttings.

Processing of uniform cuttings requires higher equipment costs than for present conventional methods. This increased cost should be more than amortized by savings in labor and machine efficiency. Employing mass production techniques, it would require comparatively large volumes of raw material and continuous operation on types of products in large demand. Lacking the flexibility of hand operated machines, it could not be proposed for products of limited volume. The main interest in such an operation will come from the opportunity to develop profit from a low cost raw material.

Possible Products From Glued Uniform Cuttings From Northern Hardwood Lumber

Customer acceptance and technical superiority of wood products glued for width are well established in the trade. From the standpoint of appearance, numerous glue lines and particularly end-joined pieces may be objectionable. For many uses where technical qualities and ability to arrange the grain of the wood are important, appearance may be a secondary consideration. In some products glue lines and joints might be incorporated for design purposes.

The technical advantages of uniform dimensioned parts for glued products are (a) reduced tendency to warp and twist in the products, (b) ability to select grain of wood to improve wearing qualities, (c) opportunity to select stock for pattern or figure.

Large scale markets, preferably consumer products, are needed to implement production from this process. A testing program would be needed to establish utility of the product.

A few specific categories of products for small uniform cuttings together with points of primary advantage might be summarized as follows:

(a) Uses where a reduction in the tendency of wood to warp and twist are important.
   1. Core stock
   2. Shoe lasts
   3. Rollers

(b) Uses in which wearing qualities are of primary importance.
   1. Bowling pins
   2. Machine and appliance parts

(c) Uses in which figure of the wood including certain defects such as stain, birds eye, etc., could add value to the product.

1. Flooring, block type or end-joined strip
2. Panels for walls or furniture

Summary and Conclusions

1. Number 3 Common northern hardwood lumber is produced in large volume and the high quality of the clear portions of this lumber is not normally a factor in its utility.

2. The major portion of low grade lumber is useable only as cut stock but the low yield of conventional dimension cutting and high preparation costs prohibit its use for high quality products.

3. Yields in small cuttings has been shown to be higher than conventional dimension stock from low grade lumber and these yields have been shown to have a predictable relationship to size of cutting. Yield increases as width and length decrease.

4. Comparatively low yields of useable cuttings must be compensated for by decreased preparation costs, and uniform sized cuttings are adaptable to low-cost mechanized methods of processing.

5. In modern concepts of wood use small size of cutting offers several technical advantages in glued products.

6. Consideration of increased yields, production cost reduction and product adaptability of small uniform cuttings constitutes a new and hopeful approach to the problem of utility of low grade northern hardwood.

Discussion

Charles M. Kreider (Elmendorf Research, Inc.): The utilization of No. 3 Common hardwood lumber has assumed increasing importance, particularly in the northern hardwood areas, where, as is pointed out in this paper, some mills average as high as 50 percent No. 3A and 3B Common.

The key to economical processing of the No. 3 Common grade of lumber lies principally in efficient mechanization of the handling of the small pieces and cuttings.

For certain specific end use products, such as flooring, it is possible today to set up a small, though highly mechanized line that can economically do the multitude of operations required on No. 3 Common to bring it into a readily saleable commercial form. An operation of just this sort will be put into commercial production by one of our clients in Kentucky in the next 90 days or so.

Cut-Stock From Western Softwoods

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The manufacture of western softwood cut-stock at the source of the lumber supply has been receiving increased attention by both the consumer and producer. Substantial savings to both can be effected by a program of research to develop further this method of delivery. Co-ordinated with this should be a research program directed toward the increased use for cut-stock of the secondary species of trees indigenous to the western softwood producing area.

Introduction

THE utilization of western softwoods for cut-stock is actually not a new development. They have been used in some measure for many years past; however some new elements have entered the picture in more recent years which have altered the general situation to a certain degree.

The entrance of quite a large number of western softwood producers into the cut-stock field is perhaps one of the more important of these elements and the one whose effect will be most widely felt. No doubt a similar situation exists in the users field, which has caused some difficulty in the equitable distribution of lumber stocks during the current, or recent lumber shortage.

Recent Trends

In recent years the trend has been toward the establishment of cut-stock facilities throughout the western softwood producing territory, so that those wood-consuming industries in other areas could be supplied with pre-cut stock of the size, shape, and quality desired. The introduction of cut-stock facilities into the western softwood producing areas was more or less of a war-born enterprise, starting largely from the critical need for crating and pallet stock. During this time most of the lumber was cut "alive" (cutting full length boards into shorter specified lengths on a multiple-cutting basis rather than on a selective basis), since the greatest need at that time was for lumber cut to exact length for crating. Generally, existing box-factory equipment was used at the start, but as experience was gained, and the need for the box-factory equipment in the production of boxes became greater, separate cutting equipment for the production of cut-stock was obtained. The advantages of cutting at the producing site became manifest, and since these advantages were very much worth while to the producer, the user, and to the lumber industry in general, the expansion of cut-stock facilities within the producing area became a matter of course.

The prime objective of this trend has been toward the reduction of cost to the user, and toward the increase of profit to the producer. A partial list of the advantages that accrue to the user through the purchase of ready-cut stock are:

(a) Reduction in transportation costs.
(b) Lowering of the raw material inventory.
(c) Elimination or simplification of waste disposal.
(d) Fairly definite raw material cost.

The advantages to the sawmill that establishes a cut-stock plant include:

(a) Utilization of slow-moving items for cut-stock.
(b) Using for cut-stock material that lumber which has to be "re-manufactured" (ripped, trimmed, or both) before being on grade.
(c) Improved waste utilization through the use of slabs, edgings, or trims for certain classes of cut-stock.
(d) Expanded use of the "associate" species of the western pines, (white fir, western larch, Douglas fir, hemlock, and western red cedar) for some kinds of cut-stock.

The savings to be achieved are substantial, but they cannot be realized without adequate research into the program by both consumer and producer.

Generally, in times past, the bulk of that portion of the western softwoods especially suitable for cut-stock, the shop and factory grades of the western pines in particular, has gone to those wood-consuming industries engaged in the manufacture of sash, door, or mill-work items, and in lesser degree to those industries engaged in the production of household equipment and miscellaneous items. This material has been, and most of it still is, delivered to the user in lumber form, the user being equipped to reduce the boards to the shapes and sizes necessary for his own particular item or items of manufacture. Some few western lumbering concerns have been engaged in the production of cut-stock for many years, but recently the number has greatly increased.

This trend has taken several forms. In some cases, sawmills that have operated for years with the manufacture and sale of lumber as their major objective, have converted to an operation with intent to use their entire sawmill out-put in their own cut-stock plant. Other plants have been built strictly as cut-stock plants and purchase their lumber from adjacent sawmills for use in their operation. Still other plants have come into being, complete with ownership of timber and logging operations, whose entire production consists of cut-stock. The number of plants in these categories, however, is not large; and for the greater share of the conversions, the trend has been toward the addition of cut-stock departments to existing sawmills, wherein the grades, species, and types of lumber most acceptable to cut-stock, which are produced within any given sawmill can be utilized in the cut-stock department of that particular mill.

An Example of a Plant Where the Cut-Stock Department Has Been Added to an Existing Sawmill

A plant wherein a cut-stock department was added to an existing sawmill is most familiar to the author, such familiarity having been achieved through the layout and construction of such a department at the parent operations of this Company. Fig. 1 illustrates the floor plan of this department, with special attention directed to the material flow and to the areas for transportation facilities. The floor plan also indicates how a transportation lane was incorporated into the design for the express purpose of providing a by-pass around the rip-saws to the cut-off saws for stock not in need of ripping, or for stock that should be cross-cut before ripping. This has proven to be very valuable in the proper manufacture of stock with the minimum amount of waste. This division of boards into "rip" type and "cross-cut" type was emphasized in a paper by C. D. Dosker,[1] presented to this Society last year, and in the comments upon that paper by others. This plant was installed within an existing building, and because of this, some compromises with the theoretical desires were necessary. Since this plant is fairly typical of other such plants in this territory, a short description of the equipment may not be amiss. The ripping portion consists of a No. 300G Hermance gang rip-saw, and a Diehl No. 75 straight-line rip-saw. There are four Irvington automatic cut-off saws and one special angle cutting saw on the cross-cut line. The moulder is a Woods' No. 137M, hopper-feed, high-speed, precision machine. The sander is the conventional top and bottom multiple-drum type. The transportation is handled by carrier or lift-truck. The finished pieces are at present bundled by hand, but an automatic tying machine is anticipated. After bundling, the stock is palletized for further handling by lift-truck. A Diehl–Dosker electronic gluer is in an adjacent room for the production of cut-stock requiring gluing into larger panels or sizes. All waste material automatically falls into waste conveyor belts, or is carried away by a suction-blower system. Additional specialized equipment will be added as needed.

Factors of Importance to Consumer

From the consumer's standpoint there are two factors that are of paramount importance to him in the purchase of ready-cut stock, and these factors apply equally, in general terms, to all classes of users.

First and foremost in importance is the source of supply. Is it reliable? Can it be depended upon to meet the users needs as required, month after month and year after year?

[1] C. D. Dosker. *Utilization of Low-Grade Hardwood Lumber.* Proc. For. Prod. Res. Soc. 2:39–45 (1948).

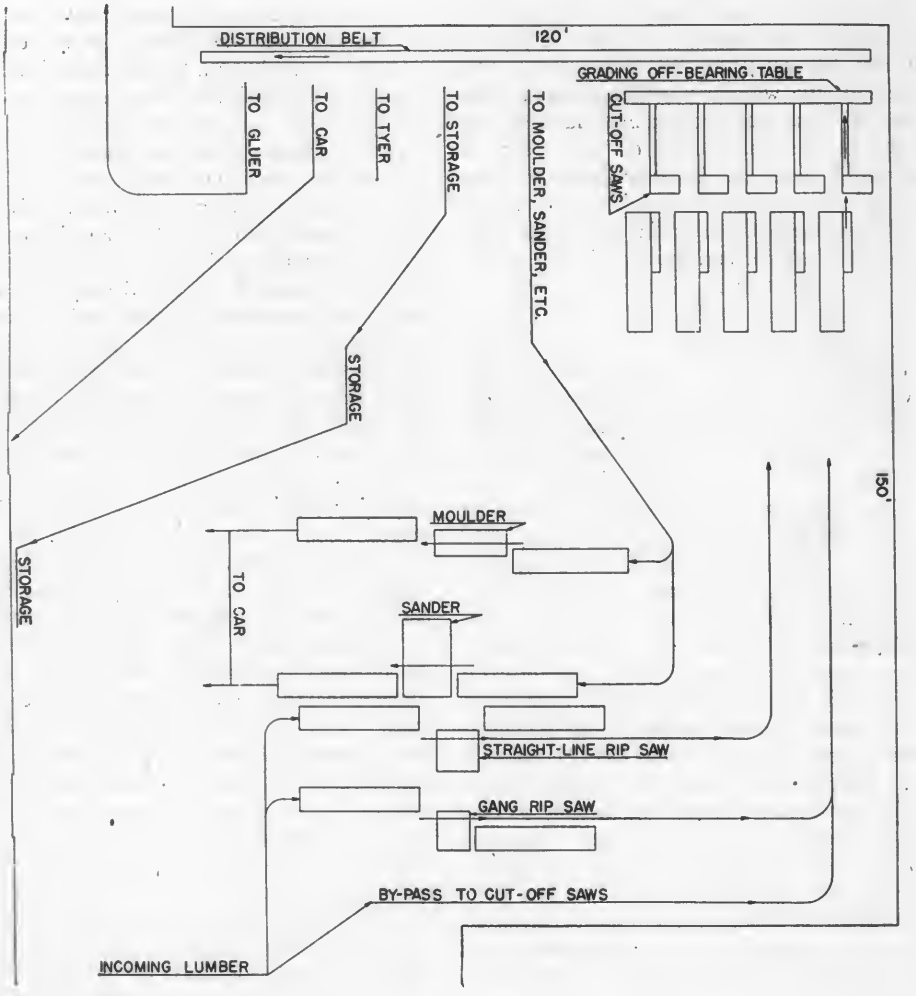

Fig. 1.

Users who have facilities for cutting stock from lumber are understandably loath to dispense with such equipment if there is any doubt as to the stability of the source of supply. It is only good common sense to make sure of an adequate, continuing source of supply before making any major changes in the operating procedure. Such reliability of source can best be obtained by an intelligent analysis of the background of the various sources offered. Unfortunately, many users have been disappointed in the past with the instability of their cut-stock supply. Generally this can be attributed to the sometimes unsavory business reputation of the supplying firm, or the user may have become involved with a concern of fairly short productive life expectancy; or again he may have been dealing with a broker or wholesaler whose source of supply has been exhausted. Such happenings naturally have caused dissatisfaction with the purchase of cut-stock to the user who experienced them and to many others who may have learned about them.

The second factor of importance to the purchaser of cut-stock is the quality of the material. This factor may be said to include the

sub-factors of grade, seasoning, and accuracy of adherence to the specifications given. No one should argue against the necessity of these requirements being exactly as specified by the customer, yet, according to the records of an investigation conducted by the Forest Products Laboratory[2] there have been instances where the loss to the user was as much as 20 percent through neglect of the producer to adhere strictly to the specifications. Considerable dissatisfaction has been caused by such practices, which reflected unfavorably on the cut-stock producers in general. Such practices are looked upon with extreme disfavor by those lumber producing firms who pride themselves upon the reliability and quality of their products, and more particularly so by those firms who have planned their business, including the cut-stock department, on a permanent basis.

Factors of Importance to the Producer

An adequate and varying order file is of greatest importance to the producer. Within certain limitations, dictated mainly by the storage capacity for finished stock, the greater the number and the more variant the size of the items on order, the more efficient is the plant operation, especially with respect to waste. For example, a specification calling for stock, say, 4⅛ inches in width, is an extremely wasteful item to manufacture. This is particularly true if it has to be made from standard widths lumber and there is no accompanying order that will work in combination with it. Regardless of the width of stock from which it may be ripped, either 6-, 8-, 10-, or 12-inch stock, a strip of odd inches and fractions is left. To keep the waste to a minimum, this strip must be used, and the best possible method of utilization is to have an accompanying order that will make the fullest use of the left-over strip. Failing this, the next alternative is to save these strips in the hope that an order can be gotten that will use them. Only a certain quantity of such items can be accommodated, however, because of the general lack of storage facilities, and eventually such items may have to be disposed of at a considerable loss. Such specifications for size naturally cost more, because of the risk involved in an excessive amount of waste. This problem is not so apt to happen if shop lumber is used in the cut-stock plant, as it is produced in random widths and fits more readily to the ripping of uneven and fractional inch widths. The difficulty lies in the fact that only a certain type of log will produce a goodly percentage of shop lumber, and that type of log is becoming more scarce, with the result that more and more of the common grades will have to be used in the production of cut-stock. It would seem that many times this problem could be eliminated, or at least alleviated in substantial degree, by engineering the item to fit standard finished lumber sizes. This problem of designing an item so as to provide for the most economical use of standard lumber sizes has been discussed before in connection with papers presented to this Society, and its importance is of such magnitude that it bears constant repetition. The continued effort of the architect and the designer in this direction will eventually result in its solution to the ultimate degree possible.

Need to Use "Secondary Species"

In the paper "Utilization of Low-Grade Hardwood Lumber", presented before this Society last year by Mr. Dosker,[1] the following statement appears: "The utilization of low-grade hardwood lumber presents one of the greatest problems facing the hardwood producing and consuming industries today". By substituting the words "secondary species" for the term "low-grade", and the word "softwood for the word "hardwood", that statement becomes applicable to the softwood lumber industry. Since the term "secondary species" may be confusing in some respects, it should be explained that this term includes those species of trees that naturally grow in association with the principal tree of an area. In the western softwood producing territory there is a marked locale of growth of the several different principal species of trees, each principal specie in turn having one or more associate species secondary to it in its particular locality. Hemlock is secondary to Douglas fir on the northwestern Pacific coast. In the western yellow pine and sugar pine areas in southern Oregon and northern California, white fir is the secondary specie,

[2] Forest Products Laboratory, Forest Service, U. S. Department of Agriculture. Cut-Stock Possibilities in Wood-Consuming Industries in Midwestern States. Report No. D1724.

and in the more arid and mountainous regions. mountain-growth Douglas fir also becomes secondary. In the western yellow pine areas of eastern Oregon, southern Idaho, and parts of the Inland Empire (a territory more or less centrally located around Spokane, Washington), white fir, mountain-growth Douglas fir, and western larch are secondary. In the western white pine, or Idaho white pine area of northern Idaho, white fir, mountain-growth Douglas fir, western larch, western yellow pine, and western red cedar are secondary.

Easily understood is the preference for the western pines and Pacific coast Douglas fir for use in the manufacture of softwood furniture, cabinet work, house trailers, prefabricated structures, and various miscellaneous items. These species are truly the "cream of the crop". Their growth characteristics produce a wood that is soft, even-textured, and in general easily worked, the pines considerably more so than the Douglas fir. Their growing scarcity, while not alarming, is something that must be given consideration by those firms, both producers and users, who plan a permanent operation. Conversely, the secondary species do not have growth characteristics which produce soft, even-textured, easily worked material. The summer wood in these species is hard in contrast to the softer growth spring wood; consequently the wood is not so easily worked, especially with hand tools. The strength characteristics are greater than the pines, and in that respect, should be more preferable for many items of cut-stock. The available volume of these secondary species is tremendous. A few specific examples of appropriate usage of these secondary species in the cut-stock field follow:

(a) White fir, a wood that is moderately strong, light in weight, light in color, and practically odorless when dry, adapts itself very readily to boxes and crating, and to the shorter items in cut-stock. By confining its use to the shorter items, which can be cut out between the knots, its tendency to warp can be overcome. Certain lay-up methods of assembly should make this wood suitable for core-stock in the moderate grades of veneered furniture. It is hoped that some work can be done in the exploration of this field.

(b) Western larch is the heaviest and hardest of the western softwoods, being very close-grained and strong. Its weight and strength make it suitable for use in cut-stock items requiring those qualities. Cornerposts of various items of furniture serve as a general example, as do certain types of toys that require a high degree of strength. It should be especially suitable in the framework of trailer houses.

(c) Mountain growth Douglas fir ranks next to western larch in strength and weight characteristics and in many items can be used interchangeably with it.

(d) Western red cedar is a wood light in weight, moderate in strength, and has a characteristically pungent odor, which none-the-less is pleasing. It is very suitable for drawer sides, bottoms, and even fronts in many types of softwood furniture. Its aromatic quality makes it semi-vermin proof, and in that respect is especially suitable for linings in clothes ward-robes, chests, closets, etc.

(e) Hemlock is extensively used for pulp, so the problem of its use is not so pressing as with some of the other secondary species.

The introduction of these secondary species into the field of cut-stock is a necessary procedure in the immediate future. The problem is one of ever increasing importance. The currently lessening demand for these species as lumber, makes it more urgently important than ever. Research—co-operative research between the producer and the consumer of cut-stock—is the best means of approaching a solution.

Discussion

G. Colluci (Southern Box and Lumber Company): The production of cut-to-size stock on the same site where the lumber is produced or kiln dried and dressed is very desirable, and I believe that from time to time, it will become more important in the marketing of forest products. The smaller the finished parts are, the greater is the yield; therefore, it shall be-

hoove the producers to develop markets for the smallest possible sizes that can be utilized.

The second thought on the subject is, that this cannot be a one-sided proposition, resulting only to the benefit of the mill and not the user. Prices should be established so that they will yield a fair profit to the mill and a considerable saving to the user. In this way, both will be anxious to develop the process.

Arlie W. Toole (Michigan College of Mining and Technology): The successful utilization of secondary species in order to extend the supply of primary species is a desirable conservation measure, and a necessity for many firms now embarked on forest management programs. Removal of these secondary species may be silviculturally desirable and the volume of material thus made available may constitute an important source of raw material for mills and plants in years ahead.

The net effect of railroad rate increases is to limit the value and grade of lumber that can be shipped to market. Under a situation of increasing rates, upper grades of the more valuable species can be delivered to the consumer at a lower proportionate cost than the lower grades. Any method of increasing the value of the product to the purchaser will tend to maintain markets for the lower grades and less-sought-after species. Production of cut stock might well be the means of accomplishing this end.

Handling of Assembly Materials in Furniture Manufacture

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Methods of speeding up and reducing the cost of assembly operations in furniture manufacture are described. A type of joint, application of glue, and method of assembly for furniture drawers are described and are said to speed up, simplify, and improve drawer assembly. The compressed tenon and mating mortise are discussed, and the advantage of this type of joint over the normal mortise and tenon is pointed out.

Introduction

IN ATTEMPTING to outline and present data on the handling of parts for assembly of furniture or any wood working item, the subject is so broad that I shall confine my comments to two or three specific problems.

Material handling from the conveyor system and the lift truck angle has been so well covered by various papers that I am not going to attempt to delve further into this but will devote myself to steps in the actual picking up and laying down of the material and rapid and accurate assembly of the parts.

In doing this I will cover three subjects: (1) the assembly of drawers for bureau drawer construction or case goods where a drawer is involved; (2) the application of the adhesive, which after all, is a material (much is being done on spreaders and so forth, but this is an application for assembly gluing); (3) the assembly of case goods involving a mortise and tenon joint, where a case clamp is used and the necessity for production results demands a short time-cycle in the case clamp.

Drawer Assembly

There are several regulation methods of assembling drawers, such as a complete dove tail or a dove tail front with a lock corner back, or, in some instances, various types of joints that depend entirely upon the glue for the strength of the joint. In all cases, the drawer clamp operation has been an assembly proposition where the entire drawer is assembled and placed in the clamp for pressing and squaring. In some cases, the drawer is placed in a clamp with the front and two sides; the clamp is tightened; the three pieces are removed, and the bottom and back put in and the piece put back into the clamp for final pressing. In the case of the dove tail drawer, the dove tail is usually of sufficient strength so that the drawer can be immediately removed from the clamp, and the glue is allowed to set at its own convenience. In the case of some of the other constructions, nails are sometimes applied while the drawer is clamped to hold it while the glue sets. In all of these cases, however, the operator has had a flimsy loose assembly of five pieces to handle, get into his clamp, and keep squared up. This has required some skill in order to speed production, and, in many instances, has led to considerable damage to the drawers, not to mention the all too frequent drawer out of square.

I should like to explain a system that is now in operation in a very sizable furniture plant in the South. This method has been studied carefully and we believe we have a very good set up for cheap drawer assembly. In the first place, the drawer sides are run on a double end tenoner. We do not use a dove tail joint. This joint depends entirely upon the strength of the glue.

Fig. 1 is a rough drawing of the type of joint that we are using. As you may note, the machining on both ends of the drawer sides is the same. This eliminates the necessity of making rights and lefts and simplifies supplying stock as well as resulting in less difficulty in over-runs or under-runs of one particular side. These drawer sides are placed in a hopper feed that is so constructed that on touching a lever, the sides come out the bottom of the feed, one at a time, passing under a very rapid pressure feed glue spreader that applies the glue in a

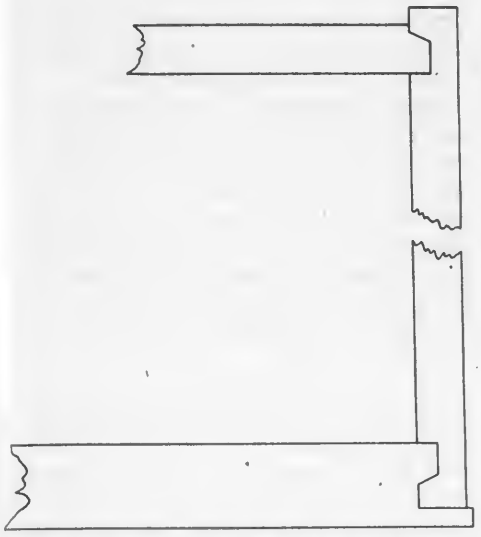

Fig. 1.—Rough drawing of drawer side joint.

fine ribbon exactly in the joint where it is desired. This eliminates smearing the glue all over the drawer sides and eliminates practically all the cleaning-up process that is usually present in the assembly of drawers.

The machinery on which these drawers are assembled is a "squirrel cage type" with five positions. The machine is indexed so that when it is ready to be loaded it is in front of the operator. The operator places a drawer front on the flat guides, picks up two drawer sides from the automatically fed glue applicator, which has applied the glue in the proper place, slides these three pieces, which he can handle easily, into position and trips the first air clamp. This clamps the front edge of the two sides to the front of the drawer and locks them securely. The locking bar is a 2-inch wide aluminum bar with an internal electric element capable of producing a temperature of 250° F. The operator then picks up the bottom of the drawer, after the first three pieces are firmly locked in place, and slides it down in the grooves, which are properly aligned with gages. He is then able to spring the drawer sides sufficiently to allow him to insert the back of the drawer. Note that the glue has already been spread on the sides prior to inserting in the machine. The operator now trips the second air clamp, which locks the clamping position at the back of the drawer. Because the front was locked before the bottom was put in and it was locked in perfectly square position, this insures squareness of lock up.

We found with this setup that after the first month of production the operator was able to make a complete cycle of five drawers in 2 minutes and 15 seconds. This cycle has been kept up at a steady rate for quite some period of time, although this does not include mixing the glue, or loading the magazine, which is done by another man.

Adhesive Handling

In the previous outline of drawer assembly, I mentioned the application of adhesive, particularly the problem of keeping the adhesive exactly where you wanted it and eliminating the necessity of cleaning up afterwards. The same problem is very prevalent in the assembly of case goods with a mortise and tenon joint. Previous practice has always been to apply this adhesive with either a brush or round stick. The glue applicator has been withdrawn from the pot and in most instances the operator applies it to the first, the second, the third, the fourth, and sometimes the fifth mortise. With this method, he usually gets too much glue in the first, slightly too much in the second, just about the right amount in the third and fourth, and in all probability, too little adhesive in the fifth mortise. It is impossible to control this type of application accurately because the worker certainly cannot afford to waste the time required to dip the brush for each mortise. Also with this method of application, the bulk of the adhesive is spread around the top surfaces of the mortise and this is not exactly where it should be. It should be down on the sides. One development which has probably helped more than anything else, and a step in the right direction, has been the application of the adhesive with a pressure gun. Most of the nozzles of these guns have been pointed so that at times the adhesive comes out through the point and at other times the point has been blocked off and the glue squirts out of two small holes at the side and back from the point. This has been fairly effective, can be controlled reasonably accurately, and, with a little skill on the part of the operators, they can do quite

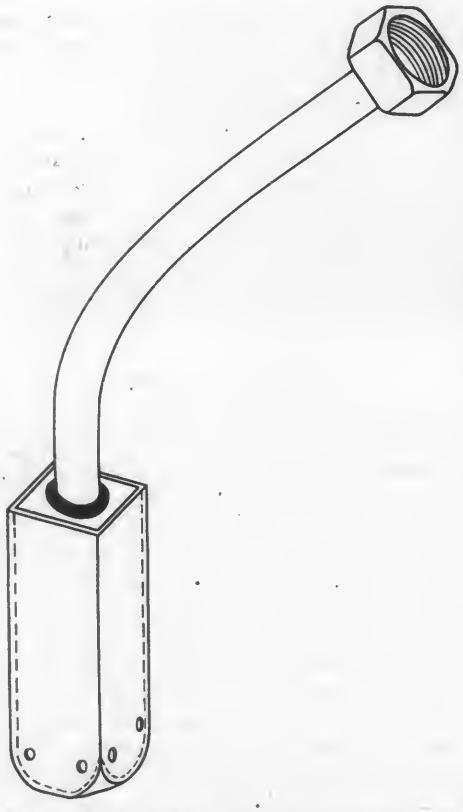

Fig. 2.—Rough drawing of device for applying glue to a mortise.

a good job with it. A new devise which we are now using very successfully for applying adhesive to a mortise is shown in Fig. 2. This is a square applicator fitted to the end of a gun; it is hollow; and has two holes on each of the four sides, slightly up from the bottom. The bottom is rounded so that the applicator can always come in contact with the bottom of the hole, even though there might be some chips left in the corner from the hollow chisel. The important factor of this applicator is the distance between the outer walls of the applicator and inner walls of the mortise. This should be gaged accurately so that the correct amount of adhesive is applied to all sides of the mortise joint. With a little skill, the operator can soon tell just when he has applied the right amount of glue. The pressure should be kept on the high side and the viscosity of the glue should also be high so that after application of the glue it will not run out or run to a position where you do not want it even with turning over or turning upside down.

With a little study of the proper air pressure back of the adhesive and the proper viscosity of the material, together with the correct size of the applicator holes, it is quite easy to have this set so that just a normal squeeze of the trigger gives the correct amount of adhesive, so that the operator does not have to do any timing. He just makes one closing squeeze and opens it immediately and the correct amount is in there.

Just as a simple explanation and demonstration of what is actually being accomplished in this even distribution of adhesive inside the hole, let us assume that we have a straight strip of glue on the flat area, that the area is 1 inch wide and 4 inches long, and that we have applied the adhesive evenly over the entire area. We now can turn this piece upside down, sideways, or endwise, but the adhesive will not run all over the surface. Now let us put this same amount of adhesive on exactly half the area, which is what is happening in the normal application of adhesive. We are covering half the area with the same amount of adhesive so naturally some of the adhesive is going to run.

Assembly of Cases Using a Mortise and Tenon Joint

In the past, assembly of case goods has demanded what we have called a "knock-up" man. This man takes up the end of the case, applies the adhesive and then proceeds to drive in the tenons with a rubber hammer. In some cases, considerable driving has to be done, as it is impossible to make perfect fits. In other cases, I have seen these tenons go in quite loosely so that the operator has trouble with them falling out in handling the case to the clamp. Also I have even seen them so tight that they have split the rail. The normal procedure from this point on is for the case clamp man to place this assembled case in the case clamp, close his clamp, and, due to the fact that his glue does not set immediately, he in most cases has to nail the joint so as to hold it until the glue has had time to set. Naturally, this nail does not hold the case as rigid and firm as the glue would hold it and if the case

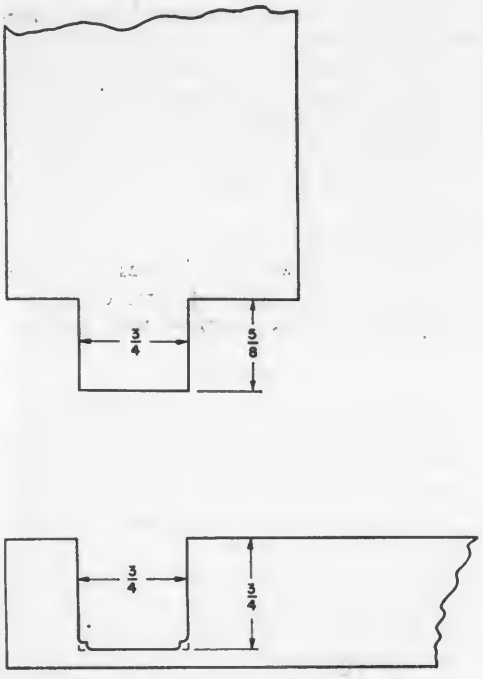

Fig. 3.—Normal mortise and tenon.

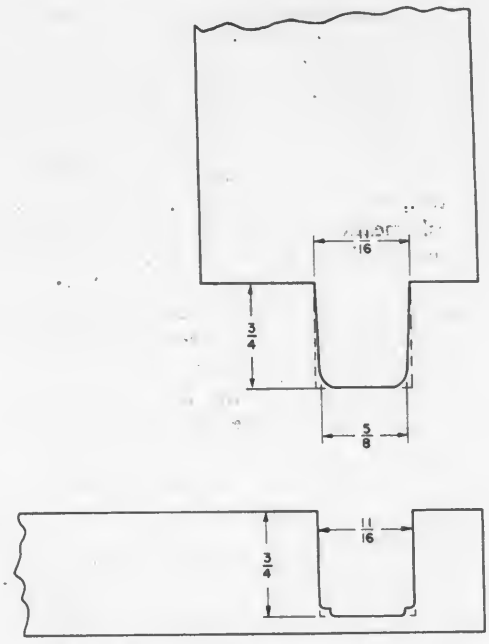

Fig. 4.—Compressed mortise and tenon.

gets a severe jar or bump immediately upon being removed from the clamp, it may be knocked out of square and cause trouble later when one attempts to fit the drawers.

Fig. 3 shows a drawing of a normal mortise and tenon joint, while Fig. 4 shows a drawing of a compressed tenon and its mating mortise, showing the differences in size. Note that the square tenon is ⅛ inch shorter. Note also the rounded end on the compressed tenon for easy entrance, which in the following set up is a very important factor. We have taken for an example the common ¾-inch square mortise and tenon joint. In normal fashion, the tenon is run on a double end tenoner from ¾-inch stock, giving a shoulder with a ¾-inch tenon, ¾ inch square. The hollow chisel is ¾ inch, giving a ¾-inch mortise. The normal set-up on this is to cut the mortise depth as deep as possible, depending upon the thickness of the end. But in all cases, there is an accumulation of chips in the corner where the chisel does not go quite so deep as the bit. Naturally it is necessary to cut the tenon enough shorter to allow for this. If the tenons are too long, the chips in the bottom prevent them from fitting tightly and there will be trouble.

We have found from experience that with the compressed tenon we can run a tenon a full eighth of an inch longer than we could with the normal setup. This rounded end on the tenon will go down into the rounded drill hole and will fit tightly when the moisture of the adhesive is absorbed.

With the compressed tenon and the draw clamp, we work with an entirely different procedure. We have racks fitted into the case clamp to receive the tenoned pieces. If the dust bottom assemblies are made up first, then the complete assembly is put in. If no dust bottoms are used, individual rails are put in position in the jig. The glue is then applied to the two assembled ends in a normal fashion. The ends are slipped into the case clamp and the clamp is closed. The operator then puts the glue into the mortise in the ends of his next assembly and assembles his rails ready to be put into the clamp. This process usually occupies anywhere from 30 to 60 seconds, which is time enough for the water in the adhesive to start the swelling action of the tenons. The

operator can then remove his case from the clamp without any nailing. The case has been found to be very firm and rigid at this point, and, as you can see, we have entirely eliminated a "knockup" man. We have entirely eliminated the possibility of split rails. The fits are bound to be perfect and one thing that is quite important, due to the glue spread applicator previously mentioned, we do not have an excessive amount of glue to be cleaned up at a later date.

I want to emphasize again that it is the rounded ends on the tenons that make possible the assembly of the case in the case clamp.

One thing that I have not mentioned at all but which is a very important factor is the increased strength of the joint. Table 1 shows the results of a test run at the American Furniture Company. The mortise end was suspended flat with the tenoned rail extending down 10 inches. A 100-pound weight was attached at the bottom of the rail and allowed to swing in a 16-inch arc. The figures shown are the number of complete swings before the joint failed.

TABLE 1.—COMPARISON BETWEEN STRENGTH OF STANDARD TENON AND COMPRESSED TENON JOINTS

Standard Tenon			Compressed Tenon		
Specimen No.	Total failure	Wood failure	Specimen No.	Total failure	Wood failure
		Percent			Percent
1	13	50	101	50	65
2	4	20	102	31	60
3	61	70	103	96	100
4	6	25	104	87	100
5	9	30	105	42	65
6	33	60	106	183	100[1]
7	22	60	107	81	100
Av.	21	45	Av.	81	84

[1]Tension failure.

Note that the strength of the poorest expanded joint was almost as high as that of the best normal joint and that some of the expanded joints showed complete wood failure.

Summary

In summary it can be said that the drawer machine eliminates one handling by using hopper feed glue applicator; eliminates glue cleanup job on interior of drawers; by two step clamping less pieces are handled at one time; and there is assurance of square drawers.

Handling the adhesive as described assures even spread, no excess glue, no running and no dripping when assembly is turned over, no cleanup job afterwards, and saving of glue.

Case assembly as described eliminates a "knockup" man, eliminates nails, gives a longer tenon, and a stronger joint.

Supplementing Wood With Metal in Furniture Manufacturing

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Dissipation of the wood supply, new methods of gluing, shortage of hand craftsmanship, and the cost, size and type of new houses have for some time been directing the attention of many furniture manufacturers toward ways and means to use other materials to replace or supplement wood.

Introduction

WHEN we look back over the past, we are brought face to face with products whose design, desirability, and price have been influenced by the use of one material as a substitute for another or used in conjunction with another. Sometimes, the replacing material has been better than that which it has replaced; other times it has not been so satisfactory but has been used because of availability and cost. More often than not, the proposed replacement material finally has been perfected to the point of serving as a supplemental material.

Take, for instance, rubber. Observe how that industry has progressed down through a long period when only natural rubber was available. We have seen costs and availability influenced drastically when there was no substitute. When synthetic rubber was introduced a few years ago, however, the whole picture changed, and rubber is becoming very much more satisfactory and cheaper for the manufacturer and user of rubber products. It is this competitive influence that is bringing rubber into use in the furniture field where it is becoming more and more acceptable.

In furniture manufacturing, we are coming face to face with this same problem as concerns the use of wood. As time goes by, wood is becoming scarcer, particularly the higher grades. Just now, a vast program is under consideration to bring about the use of low grade woods for various purposes in the wood working industry. The lack of hand craftsmanship is a problem now and will be more so from year to year. Do not overlook this last statement.

Examples of Metal Used With Wood in Airplanes and Motor Cars

During the war, we saw the Army turn to wood for the manufacture of certain airplanes because steel and aluminum had become scarce; but just as soon as the metals became more plentiful than wood we saw them switch right back to metal, even though a great many of the users of airplanes were very much more in favor of wood.

During World War II, we dissipated our supply of fine woods to the point that furniture manufacturers today are faced with a difficult problem indeed to secure enough of the material to make the kind of furniture that they would like to make and stay within a reasonable cost. A great many furniture manufacturers have learned through their war experience that they can use metal to reinforce certain pieces of wood and cut down the size of the piece of wood which they would otherwise use. This was learned in airplane manufacturing and it is also being copied in station wagon body manufacturing today. Most of the leading motor companies are bringing out a station wagon body that is made of a combination of metal and wood, and it is a very satisfactory product.

In 1946 the writer supervised the manufacturing of a combination wood-and-metal station wagon body. The roof, which had formerly been fabric and wood and which decayed quickly, was made of metal. The panels were made of wood glued to metal, and the framework was made of wood and reinforced with metal. The floor was part wood and part metal. The test drive of this car proved conclusively

that it was one of the best station wagon bodies that had ever been manufactured. The writer personally drove this station wagon 6,000 miles and it was afterwards driven 15,000 miles under test by a factory test driver. Many of the automobile distributors on the East Coast said it was one of the most comfortable, noiseless cars they had ever used, and it stood up under a wide variety of rigid tests. As a consequence of this, one of the big three of the motor companies is now introducing a station wagon body manufactured by following many of the practices that were established in 1946 in this station wagon body.

Influence of Glues and Electronic Curing

The making of wood-and-metal combinations has been made more practical by the introduction of resin glues during the last quarter of a century. Now it is a comparatively easy process to join metal to wood with glue and have a good, strong joint that will not separate with the introduction of heat, moisture, vibration or other joint destroying factors. Electronic gluing is being more widely used.

In 1944, the writer made a written report to a large corporation with the prediction that within less than 5 years gluing of wood to wood and wood to metal by the electronic curing process would have passed the primary experimental stage and would be going forward toward the perfection stage.

Specific Examples in Furniture Manufacturing

Getting down to specific cases or how it is possible to use metal in furniture without getting away from the wood feeling which all of us like in furniture, we will take a few examples and point out specifically how we can proceed. For instance, consider a table desk made with a cantilever top. Where this top hangs over the support, it has a tendency to droop. In order to prevent this, it has been a practice with the factory to inlay a piece of metal ¼ inch thick and ½ inch wide into the edge of the core and screw it fast to the end of the top. Right over this metal is glued a piece of veneer or a strip of light wood. The drooping is immediately overcome and the top is very rigid, while the appearance is not at all impaired.

In another case where a very narrow rail was needed for appearance sake, there was nothing to which the legs could be doweled and make a substantial piece of furniture. A piece of angle iron was welded to the shape of the base of this table, the rim was screwed from the inside to the metal and likewise the legs were anchored to it with an angle extending down the leg and inlaid into it. A piece of wood was glued over the metal, thereby hiding the metal reinforcement. The upper end of the angle was welded to the metal frame. As a consequence, a very rigid frame was formed and, although it didn't look like there was very much to hold it, it was more rigid than a wood rail two or three times as wide doweled to the legs and with no reinforcement.

On many upholstered pieces where a very narrow base is required for appearance sake, such as many of the modern pieces that are made today, the rail can be reinforced with metal at the back and to this metal, a spring unit can be attached. There will be no exposed metal in use but the piece will be very rigid, in fact, much more rigid than if made entirely of wood. The saving will be considerable because the metal will be much cheaper than the wood and also stronger.

A medium-sized draw-end coffee table is now being made with very small metal-reinforced wood slides. Small wood bed rails can be made with metal reinforcements that will also serve to support the box springs. Book shelves with inconspicuous metal supports are being widely used.

We have found in recent years that the matter of placing a dust panel under each drawer in a wood case is a sheer waste of material and labor. Many manufacturers today are getting away from this practice. As a consequence center guide drawers cannot be used, but drawers have to be supported on the sides. Wood slides are not sufficiently satisfactory and all metal slides are too noisy, so a combination of metal and wood slides are applied.

In the matter of fastening on panels, such as certain case backs or panels that would need to be removed from time to time to make certain adjustments, the old practice of screwing these on with wood screws is becoming obsolete. Friction socket pins are going to be used more and more as these can easily be removed with

a pair of pliers or by giving them a flip with the screw driver. Without much question, this type of pin will be used extensively in the future instead of so many wood screws that sooner or later come loose or are so tedious and hard to remove. Also when screws are inserted crooked, they present a very unsatisfactory appearance and are costly. The socket installation can be made very much cheaper than the wood screws and will serve the purpose better.

Experiments are being conducted today to develop certain wood supports for chairs to be made of molded plywood and held together with metal tubing and screws. It will then be possible to manufacture the chairs, ship them in a knocked down form and subsequently put them together with nothing more than a pair of pliers and a wrench. These chairs will be comparatively light because the rods and pipe will be made of aluminum alloy. The plywood frame will be much smaller than those made of solid wood and the appearance will conform much better to the modern houses that are being built today. It is expected that there will be little or no breakage.

Objections Removed or Lessened

Future objection to the use of metal is going to be lessened because we are using more and more in the construction of the home. Take for instance, radiant heating that is being put through metal baseboards and necessitates the using of this type of a board instead of the typical wood baseboard in a house. People will object no more to a little bit of metal in their furniture even where it is visible than they do to certain structural parts of the house. For other examples, look what has happened in the kitchen, breakfast room, sun porch, and recreation room furniture.

Suggestions to Furniture Manufacturers

It behooves every manufacturer of wood furniture today to keep before him constantly the mental picture of the piece going on the designer's table and keep the picture there until the sample is ready in the shipping room. He should determine at what point he might introduce a little metal to reduce the amount of wood he is using, make a better piece of furniture, or make it cheaper. You may have noted in one of the national magazines a plan to manufacture aluminum wire in almost unlimited quantities. If we can manufacture wire, we can manufacture rods of any size, angles, channels, and any other forms that might be applicable to the making of furniture.

Why not make a table of a combination of wood, glass and aluminum? Why not make a table, the top of which cannot be damaged by being exposed to alcoholic beverages and solvents and yet will have the advantage of wood as well as metal? The aluminum part will be strong and can be finished in any color desired. The finish can be baked on to the part where it can not be easily chipped or it can remain in a natural state, be antique or finished in most any finish that would suit the customer's fancy. There is a vast field for the promotion of this type of construction and it is going to be pioneered and promoted extensively during the next few years. Each wide awake manufacturer should alert his organization to what he may be compelled to do either from a cost angle or lack of wood raw material during the next few years.

Summary

There is a lot of wood available—its replacement is very vast indeed—but the grades are becoming lower and lower. It is going to be more and more difficult to make a suitable product entirely of wood without increasing the cost to the point where too few people will buy it.

Like every other worthwhile project to be pioneered, the answers will not come easily. The wood working industry has been old-fashioned and slow to introduce new ways and means of doing things. They have seen more and more money go for other products introduced by more alert manufacturers. More of this spending power should be used to buy furniture. Some supplemental use of metal will tend to cut production costs, making it possible to reduce prices, and by so doing, increase volume of sales in furniture.

The use of other materials to supplement the use of wood provides more wood to use where it is most needed to preserve the qualities which continue to sustain the demand for wood furniture.

Furniture is today used less carefully than it was by our ancestors. There are many contributing reasons for this harder usage. Furniture of smaller outside dimensions, of the same comfort and more serviceable qualities is in demand. Furniture of good design and quality finds an expanded market if the price is reasonable. Take a hint from recent automobile advertising of a new model—same size on outside but more room inside.

Surely this is sufficient evidence to stimulate some awakening and progress in this field. The Forest Products Research Society should not build a wood fence around its progress, but instead leave at least an open gate made partially of metal.

Discussion

C. D. Dosker (Gamble Brothers): Mr. Gividen has just stated that furniture should be simplified and more composite construction should be used. His illustration that metal should be used in unexposed parts in upholstered furniture takes away a market for low-grade lumber. There is no shortage of wood. The shortage is of high quality material and we need these uses to utilize the low-quality wood. We also have a shortage of knowledge on how to use wood to make the most satisfactory furniture without metal. I want to emphasize that we need to develop as many markets as possible for low-grade lumber.

Carl A. Rishell (National Lumber Manufacturers Association): I think that the exchange of ideas which took place between Mr. Dosker and Mr. Gividen was healthy. Neither of these gentlemen is so thin skinned that he would take offense at the remarks of the other, but it was unfortunate that there was not more opportunity for additional comment.

I suspect that Mr. Gividen intentionally injected a controversial issue for the purpose of getting just such a rise as he did out of Mr. Dosker.

As I understand Mr. Gividen's paper, he submitted two reasons why furniture manufacturers should combine metal and wood in their products.

1. That through such combinations a stronger and more satisfactory product can be made.
2. That by combinations of wood and metal the resultant increases in strength will permit the reduction of the amount of wood used in an assembly and thereby conserve wood.

I heartily agree with Mr. Gividen that composite construction is desirable and should be encouraged. Anything that we can do to improve the quality of wood as a basic raw material in the manufacture of products is correct procedure.

There are many illustrations that could be used. I believe Mr. Gividen mentioned the steel-wood construction of the present station wagon body. I wish that more wood could have been used because many of the station wagon bodies are to all intents and purposes of all steel construction. The wood used is for decorative purposes only. I might say in this connection that our wood people have no right to complain of this loss of market. It isn't the present body with the minimum of wood in it that has sold the new type, but it is the all-wood body that was so poorly constructed that it came close to unselling everyone familiar with its weaknesses. Only a year or so ago wood had no competitor for this market. With a slight amount of intelligent development of new and more durable designs, the wood industry could have retained this market probably forever. Now it is gone forever.

Had Mr. Gividen confined his remarks to this line of reasoning and extended them to other products as well as furniture, he would have presented the lumber manufacturer and the wood user with constructive thoughts that might have caused some of them to improve their products. Even one or two influential firms led in the right direction can in the end result in influencing for the better a large section of the industry.

I believe that Mr. Dosker's principal criticism did not pertain to composite construction when it is used for the purpose of improving a wood product. Mr. Dosker's own firm utilizes composite construction to the fullest extent.

Without getting into the controversial subject as to whether "forest growth" and "drain" are in equilibrium, and as I view the matter it is immaterial to this argument whether it is

or not, I believe we can definitely prove that the proper way to attain conservation is not to limit the use of wood in fabricated products.

It is true that as the old, overripe virgin timber is less plentiful, it is being replaced by second growth timber of good quality. I think it is logical to expect that extremely wide boards, such as are found in the grade of panel poplar, cannot be obtained from this timber. As a matter of fact, we don't need these extremely wide boards. With modern glues and modern gluing technique, we can make a much more satisfactory panel today out of a number of boards than we could out of a single wide board as was the practice a few years ago.

Finally, conservation to the fullest extent can only be attained through continuous and larger use of forest products, particularly the lower grades of material.

Mr. Gividen: The use of metal in conjunction with wood as outlined, will not lessen the use of wood but rather will increase it. As stated in this article, a great many places, wood has been turned down entirely in favor of metal because the wood manufacturer did not see fit to use metal to supplement construction in order to maintain appearance and at the same time insure enough strength. The example of the desk and the coffee table where the strength necessarily could not be accomplished by the use of wood only but by the use of a small amount of metal, a much better item was produced. They would have been thrown entirely out of the line if we had tried to continue to manufacture them entirely of wood, whereas the use of an insignificant amount of metal accomplished and produced a great amount of furniture that would never have been sold at all except for the supplemental use of the metal.

The fact that we have plenty of low grade wood to make upholstered frames is entirely beside the point because in the reference made to upholstered furniture the wood that had to be strengthened by metal was an exposed wood of a high grade quality and not an unexposed wood of a low grade but under no condition could wood alone be used without an unacceptable design change.

A study of my whole article will divulge the fact that at no time do I advocate to use less wood but only to supplement high grade wood with small amounts of metal in order to increase the acceptance and sale of the wood furniture. The wood manufacturers have retarded their sales by refusing to use small amounts of material to supplement wood to produce a better article. The reference to the station wagon is one of the best illustrations. If the manufacturers 20 years ago had used some more metal in their station wagons and eliminated the objectionable parts that were made of wood and fabric, they could today be still enjoying a remarkable market in station wagon bodies made with considerable more wood in them than is considered acceptable at the present time. Instead of doing this, they were not alert or else opposed the idea and their market for wood station wagon bodies is rapidly disappearing. You can see this in other items other than automobiles, and we are on the same road in furniture making unless we do make furniture which is lighter in weight by using wood and strengthening it so it doesn't have to be too bulky. If we hold off too long, much furniture will be made as a part of the house and is likely to have but very little cabinet wood in it. It will be made in such a way that the only wood that will be used will be the same type of wood that is used in the ordinary trim of the house. To counteract this tendency, make some furniture of cabinet wood of sufficient dimensions from design and strengthened at the vital points so it will not be so bulky and so expensive and will have style appeal that does not exist in bulky wood or built-in furniture.

People still want wood furniture, particularly in the higher grades but they don't want furniture made out of inferior wood which causes them trouble or looks cheap and before they will accept it, they are going to do something else. Use wood of sufficient quality and dimension for the exposed parts, supplement for strength by the use of a little metal, make the interiors out of the cheaper wood and then we will have a composite construction that in the overall picture will use up much more wood in furniture for the simple reason that much more furniture will be bought. If we don't do this, we are going to use less wood in furniture just as it is happening in station wagons, simply because people will not buy furniture of fine wood that is not strong enough to

stand up; neither will they buy it out of cheap looking wood or wood that is of insufficient strength to withstand usage. Rather than do this, they will pursue other courses as heretofore outlined and we will lose more and more wood furniture sales.

All we have to do to substantiate these facts is just to look over the building, machinery, airplane, railroad, and appliance industries and now furniture. You see an unmistakable drift detrimental to our industry. Wood furniture still has the advantage and if we wake up to what still can be done, we people who are making furniture and particularly modern furniture will be enjoying a wood furniture business for years to come if we will only be sensible and progressive enough to make it along the lines that have been outlined.

Certainly, this is a controversial subject; it always has been and will remain so because there is so much room for progress. We do not progress when we try to defend a position that is taken because of precedent or tradition. Individuals or business are retarded or fail because of refusing to recognize unmistakable trends.

I have been in the wood working industry for more than 45 years and I can see the handwriting on the wall and am doing my very best to awaken some of our most interested people in this subject in order to prevent us from losing more ground. Just look what happened to the Wood Transport Plane during World War II. According to reports, the wood transport plane was thrown out because of one accident that happened and all because the engineering of the connection between the wing and the fuselage was not properly done. It was not the fault of the wood parts at all, it was the fault of the joinery. This joinery was made in such a way that the whole fault was laid at the door of the wood plane because there were certain prejudices. If the wood engineers had insisted that the proper metal connection be made, the accident would not have happened and wood would not have received another demerit mark.

Most people appreciate fine wood items but don't want them joined with wooden pegs or reinforced with clumsy pieces of wood, nor do they want the sleek, acceptable lines of the design ruined by the clumsy wood joinery because a lot of people are not modern enough to use a better material for joinery and reinforcing.

FOREST PRODUCTS RESEARCH SOCIETY

Effect of Extending Hot Press Urea Resin With Different Types of Wheat and Rye Flour on the Strength and Water Resistance of the Glue Joints

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Glue tests were made to determine the suitability of various flours as extenders for urea resin glues. There are many satisfactory flour types that will meet mixing and strength standards. The soft wheat flours are easily mixed and do not require much water. The viscosity of the mix adapts itself to a good spread. The shear strengths of glue joints are fair. The hard wheat flours are more difficult to mix because they require more water and their viscosity is more difficult to control. Their glue-joint shear strengths are fairly high and in some cases their water resistance is good. The Durum flours require considerable water but the strength values of glue joints are good. The viscosities of the mixes are quite high. Of the rye flours, the white rye showed good mixing properties and good strength values. The dark rye is very difficult to mix beyond 25 percent flour extension.

Introduction

MOST users of urea resin in the woodworking industries use some flour extension in their resin. This has been a common practice for some time. The purpose of extenders is usually to decrease glue line costs. Despite the fact that large quantities of flour are used for this purpose, there has been little work done to determine the best flour to use. There have been many opinions voiced as to the relative merits of the different types of flour. In many instances users purchase the cheapest flour available and in other cases they merely purchase the first flour that comes to hand.

We have been confronted with this problem along with the other users of urea resin. However, during the war years when supplies were uncertain, very little was done to solve it. Shortly after the end of the war, we began preliminary tests on various types of flours. It was difficult to secure information concerning the quality of many of the flours, but we continued our efforts and feel that we can report results of value.

All of our completed tests are short term tests. The results on the high humidity exposure and weathering tests are not complete so they will not be mentioned here.

Materials

Types of Flour Used

To run these tests we have used several different types of flour. We dealt mostly with wheat flours; however, we did use some of the rye flours and will include some of the test results.

The types of flour used were as follows: Hard Winter, Second Clear; Hard Winter, Straight Grade; Hard Winter, between Straight and Clear; Hard Winter, Clear; Soft Winter, Cut-Off; Soft Winter, Straight Grade; Soft Winter, Clear; Durum Wheat Product; White Rye; Dark Rye.

All of these flours have been used in various amounts for extending resins. The extractions beyond second clear are not very suitable for extension because of their high ash and protein content and the amount of water required in the mix.

Flour Characteristics

The following flour characteristics are important in formulating resin mixes: 1. bleaching, 2. granulation, 3. protein content, 4. ash content, 5. moisture content, 6. phosphate presence, 7. viscosity.

The influence of these characteristics can be summarized as follows:

1. *Bleaching*

Flour that is unbleached seems to work better than bleached flour. Bleaching of flour decreases pot life of the resin and increases viscosity.

2. *Granulations*

Any fine granulated flour is suitable. Ordinarily, a 10xx granulation is suitable.

3. *Protein Content*

Protein can vary from 8 to 15 percent depending on the amount of extension desired and viscosity and solids content to be maintained. The higher protein flours need more water. Hard wheats, durum wheats and dark rye flour have the higher protein contents. The soft wheats ordinarily run under 10 percent protein. When certain amounts of soluble protein are present, foaming of the mix results. This can be remedied by using lower protein content flour.

4. *Ash Content*

The ash content is a factor in the final viscosity of the mix. The limits should be from 0.45 to 0.90 percent. Soft wheat flours should average from 0.45 to 0.70 percent while hard wheats, durum wheat and rye will run higher.

5. *Moisture Content*

The moisture content is usually 12 to 14 percent as milled. If the moisture content is higher, a lumpy mix will often result.

6. *Phosphate Presence*

Flour should be phosphate free to curtail foaming.

7. *Viscosity*

There are different methods used in determining the viscosity of flour at various mills. Some use the one hour digestion method while others use the MacMichael. Hard wheats have a higher viscosity than the soft wheats. The higher viscosity flours ordinarily give a higher viscosity glue mix. Hard wheat viscosity should be about 40 to 70, while soft wheat should run about 20 to 50.

The rye flours generally are not so suitable for use as extenders as wheat flours. White rye flour is suitable, though usually quite expensive. Medium rye rates below wheat flour and dark rye flour is generally not suitable because of its high ash and protein values.

Procedure

Test specimens were taken from panels glued with 60 different glue mixtures. The flour extensions ranged from 0 to 100 percent of resin solids, but the catalyst-to-resin ratio remained constant. The extenders used were the 10 types of flour previously listed. There were 15 different flours used, but some of them fell in similar classifications. The resin used was a urea-formaldehyde type, Casco 5 from the Borden Company, which contained 70 percent solid resin for each 100 lb. of liquid resin. Additional water was added to the mix to make it spreadable when flour was added. The viscosity desired was between 15 and 20 degrees MacMichael with a number 20 wire. The solids content of the mix was not allowed to drop below 50 percent.

The mixes used were as follows:

	Constituents	Parts by Weight	Percent Flour Extension
(1)	Resin	100	0
	Hardener	3	
(2)	Resin	100	25
	Hardener	3	
	Flour	17.5	
	Water	17.5	
(3)	Resin	100	50
	Hardener	3	
	Flour	35	
	Water	55	
(4)	Resin	100	75
	Hardener	3	
	Flour	52.5	
	Water	90	
(5)	Resin	100	100
	Hardener	3	
	Flour	70	
	Water	113	

The soft wheat and the white rye flours were the easiest to mix. Their viscosity averaged 15 degrees MacMichael on the No. 20 wire.

The hard wheat and durum wheat flours proved to be more difficult to mix. In some cases additional water had to be added to bring the mix to a workable viscosity. Their viscosity averaged 20 degrees MacMichael on the No. 20 wire.

The dark rye flour was very difficult to handle in the more highly extended mixes, and

the mix was too heavy to use. Excessive water is needed in these mixes. The low extension mix was satisfactory.

The veneer used was $\frac{1}{16}$-inch yellow birch of good quality. The moisture content of the veneer was 6 to 8 percent. The panels glued were all 30 by 30 inches in three ply panels. The panels were allowed to return to the 6 to 8 percent moisture content before testing.

The gluing conditions were held constant throughout the tests. The glue spread averaged from 35 to 40 pounds per 1000 square feet of single glue line. The assembly period between spreading and gluing ran from 10 to 15

TABLE 1.—AVERAGE DRY SHEAR STRENGTHS AND PERCENTAGE OF WOOD FAILURE

Test No.	Type of Flour	Percent extension 100	75	50	25
1	Hard Winter 2nd Clear	436– 9	394–11	405– 9	363–16
2	Hard Winter Straight Grade	475–73	518–54	507–26	497–44
3	Hard Winter Between Straight and Clear	498–27	413– 8	480–72	415–80
4	Hard Winter Clear	363– 6	457–40	453–59	439–17
5	Soft Winter Cut-Off	362–26	378–13	413–17	502–35
6	Soft Winter Straight Grade	380–15	400– 9	406– 5	392–43
7	Soft Winter Clear	384– 4	296– 4	411–26	311– 4
8	Durum	393–62	439–67	476–76	408–74
9	Soft Winter Clear	303–69	328–35	363–23	331–90
10	White Rye	443–28	407–26	296–53	337–77
11	Hard Winter Clear	408–49	354–43	472–74	370–82
12	Hard Winter Between Straight and Clear	323–33	299–45	249–51	346–82
13	Soft Winter Clear	411–41	408– 8	416–14	478–84
14	Durum	312–60	342–67	335–79	407–57
15	Dark Rye	------	------	------	376–44
	Unextended glue mixes				
16		352–62	------	------	------
17		442–78	------	------	------

TABLE 2.—AVERAGE SHEAR STRENGTHS AFTER 48-HOUR SOAKING IN WATER AT 25° C.

Test No.	Type of Flour	Percent extension 100	75	50	25
1	Hard Winter 2nd Clear	211– 7	242– 5	397– 7	313– 3
2	Hard Winter Straight Grade	267–15	306–25	326–19	362– 31
3	Hard Winter Between Straight and Clear	322– 8	282– 3	475–79	434– 40
4	Hard Winter Clear	158– 5	246– 6	277– 4	357– 6
5	Soft Winter Cut-Off	242– 5	198– 4	328–28	421– 51
6	Soft Winter Straight Grade	204–15	256– 3	383–16	349– 35
7	Soft Winter Clear	165– 3	164– 2	337–21	166– 4
8	Durum	305–16	395–68	408–75	423– 53
9	Soft Winter Clear	279–51	272–12	212– 9	420–100
10	White Rye	236– 4	273– 5	320–50	378– 94
11	Hard Winter Clear	246– 5	247–10	309–21	351– 64
12	Hard Winter Between Straight and Clear	256–23	300–13	283–26	390– 71
13	Soft Winter Clear	265– 9	236– 6	332–28	390– 77
14	Durum	313–51	316– 9	140– 3	247– 16
15	Dark Rye	------	------	------	343– 30
	Unextended glue mixes				
16		388–74	------	------	------
17		424–86	------	------	------

TABLE 3.—AVERAGE SHEAR STRENGTHS AFTER 3-HOUR SOAKING IN WATER AT 145° F.

Test No.	Type of Flour	Percent extension 100	75	50	25
1	Hard Winter 2nd Clear	219– 5	298– 5	347–10	286–10
2	Hard Winter Straight Grade	279–10	298–15	295–12	338–15
3	Hard Winter Between Straight and Clear	224– 7	190– 5	384–14	349– 7
4	Hard Winter Clear	152– 3	238– 7	240– 6	281– 5
5	Soft Winter Cut-Off	178– 3	171–13	370–11	347–20
6	Soft Winter Straight Grade	159– 4	237– 4	294–20	327–21
7	Soft Winter	188– 8	153– 5	292–22	173– 2
8	Durum	308– 5	316–29	351–34	384–19
9	Soft Winter Clear	[illegible]9– 9	213– 7	225– 5	416–65
10	White Rye	[illegible]– 3	242– 8	246–27	301–31
11	Hard Winter Clear	2[illegible]– 5	247– 9	306–19	303–25
12	Hard Winter Between Straight and Clear	29[illegible]– 6	267–25	282–26	363–39
13	Soft Winter Clear	20[illegible]	240– 7	415–86	303–11
14	Durum	212– [illegible]	220– 9	299–23	377–39
15	Dark Rye	------	------	------	325–25
	Unextended glue mixes				
16		455–23	------	------	------
17		463–82	------	------	------

TABLE 4.—RATIO OF DRY TO WET STRENGTH VALUES AFTER 48-HOUR SOAKING AT ROOM TEMPERATURE[1]

Test No.	Percent extension			
	100	75	50	25
1	48– 78	66– 27	65– 78	86– 19
2	56– 21	56– 46	64– 49	73– 70
3	65– 30	68– 38	99–110	104– 50
4	39– 36	54– 15	61– 07	64– 35
5	67– 19	52– 31	90–165	84–146
6	54–100	64– 33	94–320	89– 81
7	43– 75	55– 50	82– 81	53–100
8	78– 26	90–161	86– 99	104– 72
9	92– 74	83– 34	58– 39	127–111
10	53– 14	67–109	108– 94	112–122
11	60–102	70– 23	66– 28	95– 78
12	79– 70	100– 29	114– 51	113– 87
13	64– 22	58– 75	80–200	82– 92
14	86– 85	92–135	42– 04	61– 28
15	-------	-------	-------	87– 30

Unextended mix (average of all tests) 103–115.
[1]All values expressed in percentages of dry test values with the dry test as 100 percent.

TABLE 5.—RATIO OF DRY TO WET STRENGTH VALUES AFTER 3-HOURS SOAKING AT 145° F.[1]

Test No.	Percent extension			
	100	75	50	25
1	50– 56	82– 36	86– 89	79– 69
2	59– 11	58– 28	58– 46	68– 32
3	45– 26	46– 62	80– 19	84– 9
4	42– 50	52– 18	53– 10	50– 29
5	49– 12	45–100	90– 65	69– 57
6	42– 27	59– 44	72–400	83– 49
7	49–200	52–125	71– 85	5 – 50
8	53– 8	72– 43	74– 45	94– 26
9	76– 13	65– 20	62– 22	125– 72
10	41– 11	59– 31	83– 51	89– 40
11	57–102	70– 21	65– 26	82– 30
12	93–108	89– 56	113– 51	105– 48
13	50– 37	59– 88	100–614	63–103
14	59– 7	79–135	89– 29	93– 68
15	-------	-------	-------	91– 68

Unextended mix (average of all tests) 117–71.
[1]All values expressed in percentages of dry-test values with the dry test as 100 percent.

minutes. A gluing pressure of 250 pounds per square inch was used in gluing all the panels. The gluing temperature used was 245° F. and the pressing time was 7 minutes.

There were 15 plywood specimens taken from each panel. These specimens were of the conventional design used in shear testing on the Riehle Shear Testing Machine. Of these specimens five were tested dry at a moisture content of from six to eight percent, five were tested after soaking in water for 48 hours at room temperature, and five were tested after soaking in water for three hours at 145° F. The averages of these values are shown in Tables 1, 2 and 3. The percentages of wet strength to dry strength and wood failure are expressed in Tables 4 and 5.

Results

This report summarizes the results recorded in the tables. The strength of dry joints was used as a basis for the calculations.

The dry shear values were usually very good and the amount of wood failure was considerable. Joints made with the lower extensions showed higher values.

The water resistance of joints made with high extensions was poor in most cases. The shear strengths were high in some instances but the wood failure was relatively low.

In the 3-hour soak test the Soft Winter Clear flour showed the best ratio of wet to dry strength. The durum, however, showed the higher values. Extensions beyond 75 percent showed low test values. The Hard Winter Straight and Hard Winter Between Straight and Clear flour showed the best values. The rye flours showed good results only in the lowest extensions.

Samples subjected to the 48-hour soak test gave higher values than those exposed to the 3-hour tests. The Soft Winter Clears here again showed the greatest decrease in value as the flour extension was increased. Strength values of most flours were good up to 75 percent extension.

The wet to dry ratios were fairly constant in all cases up to 75 percent extension. Where original strengths were good the wet strength was good. The wood failure, however, was inconsistent in many cases.

Conclusions

Several grades of flour were found suitable for glue extension. The soft wheat flours were more easily mixed than the other varieties. The viscosity of the mixes was suitable for spreading in all cases. The lower extensions with soft wheat flours required very little water to maintain the desired viscosity.

The hard winter wheat flours were quite difficult to mix especially in the higher extensions. In some cases more water was required than was practicable in the 100 percent extensions. The mixes were easily made in the other extensions. The strengths of the Straight grades and Straight to Clear grades were good in many cases.

The white rye flour was easily mixed. The values were not too satisfactory beyond 50 percent extension. The lower extensions showed good values and good ratios. The dark rye is not too suitable in the higher extensions. Too much water is required to get a spreadable mix.

No definite conclusion could be drawn from the ash or protein values. It was noticed, however, that as these values increased it became more difficult to mix the glue. It will be necessary to continue these tests further on both a short and long term basis before the best flours can be determined. All of the flours except dark rye mentioned can be used for urea resin extension if extension does not exceed 100 percent. The long term exposure tests should prove to be of additional value in making the final conclusions.

Evaluating Furniture Finishes

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This paper deals with the evaluation of clear or transparent furniture finishes, defines them and discusses their production, requirements, materials from which they are produced and composition. The wide diversity of prices at which these materials are offered and the relationship between price and results is discussed. The users of furniture finishes are urged to evaluate by careful testing the present and future qualities, or serviceability, of finishes they contemplate using in order to assure themselves of the suitability of the finish for the particular product being manufactured.

TO UNDERSTAND and evaluate furniture finishes, and the materials with which they are produced, it is necessary that an unfortunate but wide-spread habit, of speaking and thinking inaccurately about them, be corrected.

The average person, speaking of or describing a furniture finish, is prone to refer to it as a "good" finish or, conversely, as a "cheap" finish. What is meant by the words "good" and "cheap"? Does "good" refer to purity of design, to inherent value, to protection features? Does "cheap" mean poor design, low price, a bargain? Generally, the meaning is not clear and is confused because recognition has not been given to the fact that there are two principal and separate features in every furniture finish.

Purpose of a Furniture Finish

A furniture finish is of two definite and distinct parts for there are two well founded reasons for finishing furniture. These are: (1) to beautify, and (2) to protect. For this reason, when it is desired to evaluate a furniture finish, it is necessary to restrict or limit the appraisal to one characteristic at a time. This is important because quality or lack of quality in one feature is not necessarily an indication quality will be present or lacking in the other feature. To express this in another way—the fact that a certain furniture finish is beautiful from an artistic standpoint is not a warranty that it is of good inherent quality or that it will provide the desired or needed serviceability. Likewise, the fact that from an artistic standpoint a furniture finish may be atrocious is not an indication that it is of poor intrinsic quality.

In using finishing materials for the purpose of beautifying furniture, we seek to produce colors, color variations, color harmonies and contrasts which, together with the transparency, depth, luster and "feel" of the coatings are pleasing, appealing and satisfying.

In using finishing materials for the purpose of protection we seek to achieve coatings that will protect the furniture from:

1. Atmospheric conditions and changes in those conditions.
   Our purpose is to maintain the moisture content of the wood as closely as possible to that prevailing at the time of manufacture. In this way wood dimensions are stabilized. Achieving this, drawers and doors once properly fitted, continue to be properly fitted and work without sticking or binding. Further, glue joints remain tight and solid and panels do not warp.
2. The hazards of normal use.
   Our purpose is to protect the wood from discoloration, soil, mars, stains and scratches.

Informative Labeling Needed

It must be readily evident that anyone can appraise (at least to his own satisfaction) the artistic quality of a furniture finish by merely looking at it. It is apparent too that the better trained, the more cultured, the more critical the individual examining the finish the more comprehensive and the more correct the conclusions.

It is unfortunate that a similar visual examination of a furniture finish, regardless of the training, the experience or the knowledge of the examiner, will not provide a basis for an evaluation of its capacity for protection. This is true for the reason that a color that is fade proof looks no different today than a color that

will fade readily, a coating (be it lacquer, varnish or synthetic) that has flexibility appears no different than one that is brittle. In short, there is not in furniture finishes a characteristic initial appearance peculiar to an inherent quality or lack of an inherent quality.

Thus it is that the protective qualities can only be determined by actually testing the furniture finish. Obviously, if the finish under test is unequal to the test requirement, the finish on the furniture is ruined.

Because there is no way in which, by visual examination, the inherent qualities of a furniture finish can be determined, it would appear highly desirable for furniture manufacturers and manufacturers of finishing materials, through cooperative effort, to establish a program of informative labeling. In this way the true protective qualities of furniture finishes could be made known to those interested. This could be patterned after the practice of the textile industry where evidence of shrink proofness, water resistance, and sun proofness, is given by means of labels and tags.

What Is a Furniture Finish?

We now come, quite naturally, to a consideration of what a furniture finish is and how it is achieved. For the sake of avoiding confusion, let us limit our present consideration to furniture finishes of the clear, transparent or translucent types and exclude from our consideration finishes of the opaque or so-called painted or enameled types. On this restricted basis then, a furniture finish is a coating or a combination of coatings of organic compounds, that produce a desired color or colors in or on the furniture woods and that produce a film that protects the furniture from changes in atmospheric conditions and from the hazards of use.

The Basic Materials

Even as the basic purpose of a furniture finish is two fold so the materials of which it is produced fall into two principal categories. There is that group of materials used in achieving the color and color effects desired and that group of materials from which the protective films are produced. Sometimes a given finishing material may serve a dual purpose.

The group of materials used for the purpose of coloring or beautifying the wood falls into two principal classifications—those formulated of soluble coloring matter, and those formulated of insoluble or pigment colors. They can also be divided in another manner, that is: as to whether the color they contribute is impregnated in the wood, lies on the wood, or exists in or between films of finishing materials above the wood.

Table 1 classifies the group of coloring materials under both of the aforementioned arrangements.

TABLE 1.—CLASSIFICATION OF COLORING MATERIALS

Coloring Materials	Soluble colors	Pigment colors
Penetrating	Water stain Penetrating oil stain Spirit stain Non-grain-raising stain	Wiping pigment stain Colors in oil (To be thinned and wiped)
Semi-penetrating (Color close to the wood)	Tinted or colored varnish Stains in Sealers	Non-wiping pigment stain
Color in pores		Filler
Non-penetrating (Color in the film laying on the wood)	Toner Shading stain Padding stain (When used over sealer) Color varnish	Pigmented sealer Pigmented shading stain Wiping Glaze (When used over a coating)

The group of finishing materials used for the purpose of forming protective films on the furniture fall naturally into two classifications —those drying solely by a process of evaporation and, those drying by a process involving oxidation, polymerization and gelation. Those materials drying by evaporation are generally formulated with a base of cellulose (it may be nitrocellulose or ethyl cellulose or some other chemical compound of cellulose) and are popularly referred to as lacquers. Those materials not drying by evaporation are generally formulated without cellulose and are popularly referred to as varnishes or synthetic coatings. The term varnish is generally used alone or with the qualifying word "oleoresinous" when the resins used in the making of the varnish are natural resins. When chemically made or synthetic resins are used the qualifying word "synthetic" is generally used with the word varnish, i.e. synthetic varnish.

The film forming materials may also be classified in another manner, that is in accordance with the purpose for which they are used. To illustrate: some coatings are used for purposes of impregnation, some for purposes of sealing the surface of the wood, and some for the purpose of building a film above the surface of the wood.

Table 2 arranges the clear, transparent and translucent film forming or protective materials in accordance with these two methods of classification.

TABLE 2.—PROTECTIVE MATERIALS

Materials	Lacquers	Varnish or synthetic
Impregnating materials	Penetrating sealers	Impregnating sealers Waterproofing sealers Insecticidal sealers Fungicidal sealers
Sealing materials	Sealers Clear coatings	Shellac Sealers Clear coatings
Coating materials	Gloss coatings Flatted coatings	Gloss coatings Flatted coatings

Tables 1 and 2 provide a listing and a classification of the important types of materials used in the production of a furniture finish.

The determination of which materials are actually used and how they are used is controlled by two principal factors—the type of wood used and the kind or quality of the finish desired. As is known, woods, from the standpoint of finishing, are of two principal kinds —the open grain type as oak, walnut and mahogany, and the close grain type as gum, poplar, beech, and maple. As is probably suspected, the quality of finishes varies over a wide range.

Basically the process of finishing open grain woods is the same as that employed in the finishing of close grain woods. The important difference is that the pores of the open grain woods must be filled to provide a level surface. This obviously is not necessary when finishing close grained woods.

Cost Relationships

In considering furniture finishes and how they are produced it must be remembered that there exists a wide range of requirements not only from the standpoint of appearance of the finish, and the quality of the finish but also from the standpoint of cost. Inasmuch as the amount of money spent in producing a finish should have a bearing on the beauty and inherent quality of a finish, it appears desirable to set up various classes of finishes, such classes determined by the amount of money available for finishing the furniture. Suppose then that three classes be established and that they be called simply low cost finishes, medium cost finishes, and high cost finishes.

Almost always, regardless of what cost classification the finish may be in, it is necessary to color the wood to achieve a pleasing, appealing and satisfying finish. Obviously, in a low cost finish the minimum effort and expense necessary to produce an acceptable color is put forth.

Having produced an acceptable color it then becomes necessary to seal the wood (to provide a barrier against the movement of moisture into or out of the wood) and to provide a level surface or foundation for the finish coat. Here again, in a low cost finish, minimum expense and effort are expended.

The minimum requirements of a finish are provided by the application of a top or finish coat over the sealer coat, to further protect the furniture against atmospheric conditions, and to protect the furniture against the hazards of normal use.

This then constitutes the minimum in furniture finishing operations when close grained wood is used, viz: color the wood, seal the wood, apply a protective coat. If the wood be a wood with large pores, it would be necessary to add the operation of filling the pores. Obviously, this minimum or low cost finish would not possess many features present in the medium or high cost finishes. For example, the color would be harsh in comparison with higher cost finishes—it would quite likely be lacking in details that contribute to interest such as high lights and shadows. Similarly in this low cost finish the thickness of the film might be less than is desired.

Aside from the refinements of color and appearance that might be lacking in a low cost finish, such a finish can be of high intrinsic quality and can provide good protection. Whether it does so or not will be determined entirely by the inherent quality of the materials used.

A furniture finish is advanced from a low cost to a high cost finish by the addition of various operations, each designed to add refinement, interest or additional protection to the furniture. These additional operations in many instances are hand operations. Sometimes in improving a finish a hand operation replaces a machine operation. Refinements in furniture finishes generally take the form of further development of color. It may be noted that as more and more money is invested in a finish, color assumes increasing importance. It will be found to achieve a third dimension, a depth, missing in lower cost finishes. It will be found to enhance, to add interest and drama to the wood grain. It will add artistry to the concept of the finish in that desirable features of old, mellowed, museum pieces of furniture are captured and reproduced. How is this accomplished? Simply by the use of color at every possible level of the finish, that is, impregnated *in* the wood, filled *into* the pores of the wood, *on* the surface of the wood and *in* the films of materials above the wood. In this way it is possible to have color at three or four levels.

In an effort to clarify further these three types of furniture finish, let us list a typical finishing procedure for

(a) A Low Cost Finish

1. Finish sand furniture to prepare for finishing.
2. Stain to desired color.
3. Apply coat of sealer.
4. Sand sealer coat.
5. Apply a flatted topcoat.

(b) A Medium Cost Finish

1. Finish sand furniture to prepare for finishing.
2. Stain to desired color.
3. Apply light coat of sealer (called a washcoat) to lightly seal the fibers of the wood.
4. Fill pores (open pore wood).
5. Apply coat of sealer.
6. Sand sealer coat.
7. Uniform color on different parts of the piece by shading the light parts to match the darker parts.
8. Apply finish coat.
9. Sand finish coat.
10. Apply second finish coat.
11. Rub finish coat.
12. Polish finish coat.

(c) A High Cost Finsh

1. Hand sand furniture to prepare for finishing.
2. Stain to desired base or undertone color.
3. Impregnate wood with water-proofing material.
4. Fill pores of wood (open pore wood).
5. Apply coat of tinted glazing sealer.
6. Sand glazing sealer.
7. Apply coat of glaze.
8. Brush and blend glaze to achieve mellowing of color and to intensify highlights and shadows.
9. Apply coat of sealer.
10. Sand sealer coat.
11. Apply finish coat.
12. Sand finish coat.
13. Hand pad color into finish coat.
14. Add distinguishing marks and treatment to finish.
15. Apply second coat of finish.
16. Hand rub finish.
17. Clean up rubbing.
18. Hand wax finish.

Attention is again directed to the fact that the principal difference between a low cost and a high cost furniture finish is in the effort put forth to develop color and the artistic treatment of the wood. Attention is also directed to the fact that regardless of whether the finish be a high cost or a low cost one the quality of the finish, the protection that the finish is capable of providing is determined solely by the inherent quality of the finishing materials used and not by the artistry or lack of artistry in developing or refining color. Thus if the most artistic, the most beautiful of furniture finishes were produced with finishing materials of inferior quality the entire finish would be inferior from the standpoint of providing protection against atmospheric conditions, the changes in those conditions and against the hazards of normal use.

Origin, Manufacture, and Properties of Finish Ingredients

To understand the matter of inherent quality in finishing materials it becomes necessary to consider the raw materials used in the formulation and manufacture of the various finishing materials and also, the processes by which they are manufactured.

This can probably best be done by providing a chart covering each type of product as shown in Tables 1 and 2. See Tables 3, 4, 5 and 6.

TABLE 3.—STAINS FORMULATED OF SOLUBLE COLORS

Name	Content	Method of Manufacture	Advantages	Disadvantages
Water stain	Water-soiubie aniline dyes	Mixing	Depth of color Brilliance of color. Permanence of color.	Raises wood grain. Long period required for drying. Necessary to sand the raised grain.
Oil stain	Aromatic-hydrocarbon-soiubie aniline dyes	Mixing	Does not raise grain. Dries quickly.	Does not produce depth of color or briiliance of color. Color not permanent. Bieeds into subsequent coats.
Spirit stain	Alcohol-soiubie aniline dyes	Mixing	Does not raise grain. Dries quickly.	Does not produce depth of coior, or briiliance of color. Color not permanent.
Non-grain-raising stain	Water-soiubie aniline dyes	Mixing under heat Filtering	Depth of color. Brilliance of color. Permanence of color. Does not raise grain. Dries quickly—a matter of minutes.	----------

TABLE 4.—RAW MATERIALS AND PROCESSES USED IN THE MANUFACTURE OF FILLERS,[1] PIGMENTED WIPING AND NON-WIPING STAINS, GLAZES[2]

Fillers consist of

- Pigments
  - Inert pigments as: Calcium Sulphate; Silica; Magnesium Silicate
  - Earth color pigments as: Siennas; Umbers; Van Dyke Brown; Etc. — and/or Soiuble colors (As in Tabie No. 3)
- Vehicle
  - Varnish
    - Resins: Natural; Synthetic
    - Oil: Vegetabie; Drying
    - Solvents: Hydrocarbons; Terpenes
    - Driers: Manganese; Cobalt; Lead

[1] Fillers are manufactured by thorough mechanical mixing and grinding.
[2] Pigmented wiping stains, pigmented non-wiping stains and glazes are all formuiated of the same basic ingredients as filiers but in different proportions.

TABLE 5.—RAW MATERIALS AND PROCESSES USED IN THE MANUFACTURE OF LACQUERS

Raw Materials	
Material	Type
Nitrocellulose	Cellulose fibers nitrated by treatment with nitric and sulphuric acids
Resins	Natural
	Synthetic
Plasticizers	Treated oils
	Chemical
Soivents	Esters
	Ketones
	Ethers
	Alcohols
	Aliphatic or aromatic hydrocarbons

Processes

All lacquers are produced by dissolving nitrocellulose, resins and plasticizers in the solvents by thorough mixing and agitation.

Lacquer Sealers

Consist of lacquers, as compounded above, to which a "sanding agent", usually a metallic soap, has been added by a grinding process.

Flat Lacquers

Consist of lacquers, as compounded above, to which a "flatting agent" has been added by a grinding process.

Lacquer Toners

Consist of lacquers, as compounded above, to which soluble colors have been added.

Lacquer Shading Stains

Consist of lacquers, as compounded above, to which have been added soluble colors or pigmented colors.

Lacquer Enamels

Consist of lacquers, as compounded above, into which have been ground earth or chemical pigments.

TABLE 6.—RAW MATERIALS AND PROCESSES USED IN THE MANUFACTURE OF VARNISHES AND SYNTHETIC VARNISHES

Raw Materials

Materials	Type	
Resins	Natural	
	Synthetic	
Oils such as	Linseed	
	Soya	
	Tung	
Solvents	Hydrocarbons such as	VM&P Naphtha
		Mineral Spirits
		Hi-Flash Naphtha
	Terpenes such as	Pine Oil
		Turpentine
		Dipentine
Driers	Manganese	
	Cobalt	
	Lead	

Processes

Varnishes are produced by cooking and mixing to achieve a chemical and physical union of the ingredients.

Varnish Sealers

Consist of varnishes, compounded as above, into which are ground "sanding agents".

Flat Varnishes

Consist of varnishes, compounded as above, into which are ground "flattening agents".

Color Varnishes

Consist of varnishes, compounded as above, to which are added soluble colors.

Enamels

Consist of varnishes (or synthetic varnishes) into which have ben ground earth or chemical pigments.

It may be noted from the foregoing tables that there are a comparatively few families of products used in producing finishing materials. They are: resins, oils, solvents, plasticizers, pigments, soluble colors, driers and chemically modified cellulose, sanding and flatting agents. It must be noted however that while the classification of products are few the number of items in many classifications is almost without limit. For example, while natural resins (those found in nature, fossilized or otherwise) are of limited number, those made chemically or synthetically are almost limitless in number and are being added to almost daily. The same situation prevails in the field of solvents and plasticizers. Pigments too are of many kinds.

This wide variety of raw materials makes available to the finishing material chemist and formulator products to serve virtually every requirement of quality or performance and virtually every requirement of cost. Either requirement can be met, but top quality at lowest price cannot very often be provided in a single material.

Thus is explained the wide diversity of prices at which materials of the same name are offered. There is but one fact of which every buyer may be certain—he is never getting something for nothing. While the fact that this is so may not always be apparent when materials are being applied or when furniture finishes are newly completed, it invariably does become apparent as the finish ages. At that time, however, it is too late to do anything about it.

It is for this reason that users of furniture finishing materials are urged to evaluate by testing procedure the present and future qualities and fitness of the materials they contemplate using, so that they may thereby assure themselves that the materials used do possess the desired protective qualities. Having done so, the sale of the furniture will be helped if a statement of the qualities of the finish are attached to the furniture in the form of an information tag signed by the manufacturer.

Discussion

G. G. Sward (National Paint and Lacquer Association): Mr. Hager has outlined the minimum requirements for getting a good finish; that is, he has itemized the necessary steps. I couldn't add a thing to what he has told us in that respect. But finishing is a cooperative undertaking. The finisher must perform each step properly and with quality materials, in order to create aesthetic as well as service value.

Mr. Hager: Mr. Sward's remarks are most pertinent and I am highly in accord with them; though to the producer of finishing materials his products are finished products, to the user they are, in effect, raw materials and what he does to and with them and how he does it will, in large measure, determine the result.

John H. Gividen (Dunbar Furniture Manufacturing Company): It has been the observation of many, who are competent to evaluate what the proper finish does as to beautification and atmosphere of the finished product, to condemn many of the finishes that are best for protection because the finish detracts from the

beauty and atmosphere. In this connection, many of the best looking finishes do not do much from a protection angle when exposed to hard usage or to unusual moisture or temperature conditions.

Furniture finishes for the most part have always been evaluated from two bases and little has been done to try to get the two bases closer synchronized to accomplish a common desirable result: appearance and utility.

Mr. Hager: No one can take issue with Mr. Gividén's comments. The furniture manufacturer has had repeated and undeniable proof that if his furniture does not possess, in color and in the artistic concept of finish, that which the consumer seeks, it will not sell, not only regardless of how good the finish may be, intrinsically, but also regardless of how good the construction may be. Therefore, it is easily understandable that the mere fact that a finishing material or a complete finish has quality, is not sufficient in his eyes to warrant the purchase of the materials offered. It must not be assumed, however, that because a given finishing material is possessed of high intrinsic quality, it is impossible or even difficult to achieve with it the color and artistic results which are demanded by the consuming public.

The alert and progressive manufacturer of finishing material who supplies the furniture manufacturer has an up-to-the-minute knowledge of the colors and the artistic effects which are sought and bought by the consumer, and offers a design service to the furniture manufacturer that results in the artistic effects that sell.

All that is necessary to achieve the results which Mr. Gividén so rightly states are desirable and necessary is for the furniture manufacturer to select as his source, a finish material manufacturer who has a forward looking concept of the furniture manufacturer's needs, and having selected such a source, to work closely with him to the end that the furniture manufacturer's objectives are successfully achieved.

Lumber Core Panels

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and
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Both of
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This paper has been prepared in an effort to provide a clear understanding of the advantages and disadvantages of the various types of edge-gluing machines available today. It sets forth the events which led to the development of present day edge-gluing equipment. Following this, the operation of each type is explained. Included, also, is a complete description of the ideal set-up for the preparation of lumber for both batch-continuous presses and continuous feed presses. This is followed by a brief explanation of the latest development in combining steam heat with high frequency heating and the advantages which result.

Introduction

IN THE middle 1930's, three European roll-feed veneer splicers were imported into this country. These machines operated in a cross-feed direction as contrasted to the usual with-the-grain direction. This led to the development of the first commercial steam-heated continuous feed lumber edge-gluing press in this country. The date was about 1940 though the experimental model was produced several years earlier.

Today we have lumber edge-gluing machines of various types—all surplanting the old-fashioned clamp carrier. These new machines may be classified as follows:

1. Batch presses
   a. Steam heated
   b. High frequency heated
2. Batch-continuous presses—high frequency heated
3. Continuous feed presses
   a. Steam heated
   b. Combination steam and high frequency heat

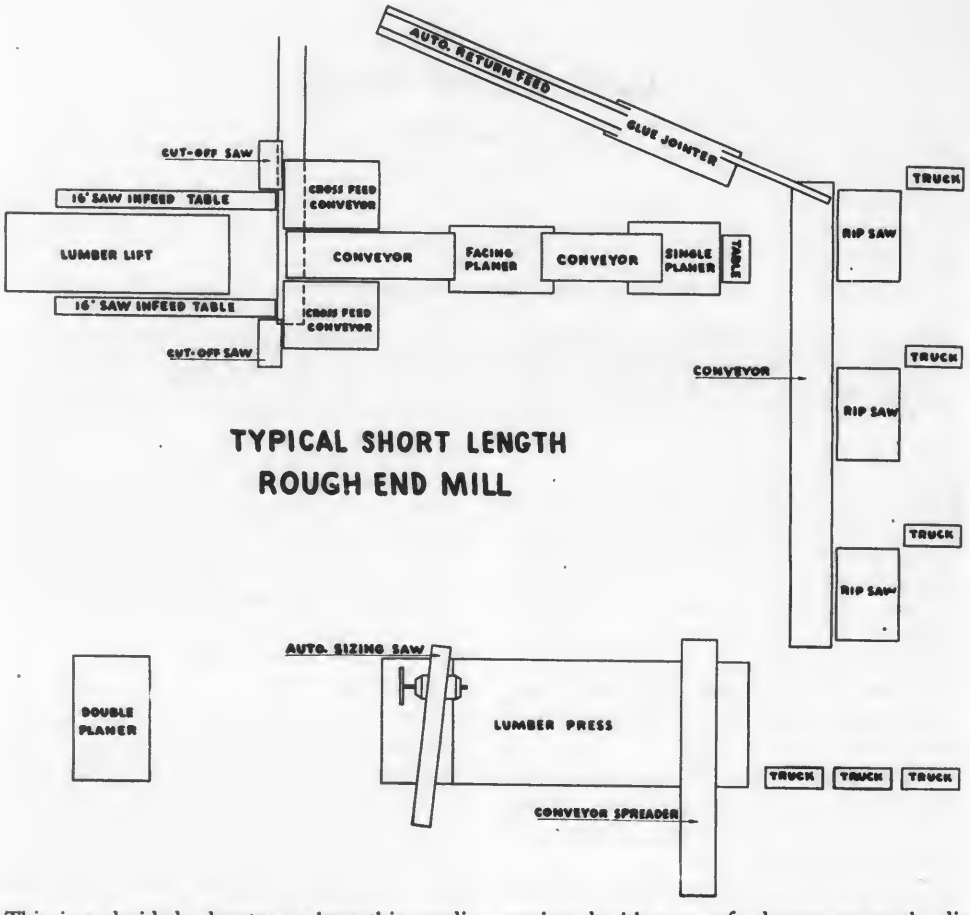
The batch presses and the batch-continuous presses usually require prematching to width of the panels or scores. The continuous feed presses are set apart by having a width-sizing saw as part of their mechanism.

When machine edge-gluing of lumber was introduced commercially in 1940, it was considered best practice to double surface the lumber in full lengths as it came from the lumber lift. The object was to provide a clear surface so that the slash saw operators could more readily see the defects. This method took out neither twist nor cup. An equally important objective was to leave as much in thickness as possible for the final planing operation behind the clamp carrier, as the clamp method did not result in flat panels or cores.

Now, with all but one of these new automatic machines, we have one thing in common; the end product, after gluing, is flat. Furthermore, it is no longer possible to pound and beat poorly fitting joints together as in the clamp carrier. Nor, it might be added, do we have internal stresses in the final product. This, of course, calls for better preparation of the lumber in order to obtain the fullest benefit from these new edge-gluing machines. And this, in turn, led to the development of the short-length rough-end mill.

Lumber Preparation

Depending upon the footage to be glued per day, the short-length rough-end mill starts with a single or a double line at the lumber lift. A single line will cut about 10,000 feet per day, while the double line approximately doubles that. With a single line, we have a conveyor at the lumber lift equipped with a hydraulic cut-off saw. Here the lumber is cut to desired lengths. Some defects are also cut out. Incidentally, a rip saw can be easily put into a single line set-up, for the purpose of splitting wide stock that is cupped or twisted.



TYPICAL SHORT LENGTH
ROUGH END MILL

This is a decided advantage where this condition exists to any appreciable degree.

Whether or not this "busting" saw is used, the boards next proceed over a roller conveyor and into a facing planer. The facing planer faces one side of the stock to provide a flat lower working surface. The stock then feeds along to a single planer where it is planed to thickness. The thickness can be much closer to the final finished thickness than was heretofore the practice, because the automatic edge-gluing operation to follow will produce a flat panel with flush surfaces. This means that much less stock needs to be removed in the final planing in order to clean up.

If a double line is used, two saw infeed tables are provided, one on each side of the lumber lift. Two cut off saws are used, each equipped with a cross-feed conveyor on the discharge side. These cross-feed conveyors transfer the cut lumber to the infeed conveyor of the facing planer. The balance of this phase of the operation is then as already described. In the ideal layout, the next step is edge-jointing the boards in a glue jointer. This machine is equipped with automatic return feed. The stock is then conveyed to a battery of straight line rip saws. Here the defects are cut out. Angling cuts are the rule, in order to increase the yield of usable lumber.

Edge Gluing in Batch and Batch-Continuous Presses

If the lumber is then to be glued up in batch presses or in a batch-continuous press, the next step is to match to width. This job is best done

on a separate matching saw of the conventional type.

Following this, the lumber cores or panels are passed over a conveyor glue spreader and are assembled on the lay-up table of the batch press. When the assembly is completed and when the press has automatically opened at the end of the curing cycle, the operator feeds the fresh assembly into the press. This simultaneously pushes out the finished panels. The "start" button is then pressed, causing the top and side cylinders to apply surface and edge pressures, following which, the high frequency generator starts automatically. At the end of the cycle—usually 20 to 60 seconds—the generator times out and stops and the side and top cylinders retract. The cycle is then repeated. In this type of press, high frequency heating is usually faster than steam heating, which explains why practically all of the batch presses in existence are H. F. heated. To put this another way, the size of the assembly table in a batch press equals the size of the press. It would be possible, for instance, to build a 4 ft. by 24 ft. steam heated batch press which would produce as much as or more than a 4 ft. by 8 ft. high frequency batch press. However, the assembly would be a problem. High frequency also has the advantage that it does not appreciably heat the wood in this operation. It has the disadvantage that it does not cure the squeezed-out resin.

The operation of the batch-continuous press is practically identical with the regular batch press in that the panels are assembled on a feed table equipped with pusher bar. The pusher bar starts the panels between upper and lower feed rolls. At this point, traveling clamps apply the side pressure and convey the cores through the machine and under a floating electrode. No flattening or downward pressure is applied beyond the infeed rolls, which presupposes unusually exact preparation of the lumber.

Edge Gluing in Continuous-Feed Presses

If the gluing of the lumber is done in a continuous feed automatic lumber press, the pre-matching to width operation required with batch presses is almost always eliminated. The automatic cut-off saw on the lumber press performs this sizing operation. The exception to the rule is when gluing up lumber for solid tops, where it is desirable to have selected outer rails.

In a typical automatic lumber press operation, the spreader feeder takes a handful of boards and stands them on edge on the conveyor spreader. This brings the boards directly in front of the press operator who grasps them and riffles them out on the feed table, butting one end against an adjustable end guide. When desired, two or more rows of short stock are run side by side. With this type of machine, the lumber is constantly moving away from the operator. This is the reason why these machines are markedly faster in production than batch type machines.

As the lumber is conveyed over the feed table, it enters between pairs of upper and lower pressure chains. This caterpillar tractor type of feed forces the lumber between pairs of top and bottom steam-heated hot plates. This is the curing section, where the resin glue is set as the stock travels. At the rear end of the curing section is located a series of hydraulically actuated pressure shoes. These oppose the forward movement of the lumber and in so doing build up any desired pressure between the joints. At the same time, the upper steam platens rest on the stock as it moves under them, thereby holding all boards perfectly flat and flush while the glue is setting.

As the continuous ribbon of stock emerges from the pressure shoes and slides out on a run-out table, the end of the now glued-together boards trips an adjustable target. An automatic cross-traveling rip saw then cuts off the desired width of core or panel. Since the saw is also traveling forward at the same speed as the stock, there is no interruption in the feeding of the stock. As the saw completes its cut, it lifts to an upper return track and travels back across the width of the machine to its starting point where it is ready for the next cut. This sizing saw, which determines the width of the core or panel, is entirely automatic and will cut one or more rows to equal width. After the cores have been cut to width, the off-bearer either dead piles or stick piles them.

After they have cooled down sufficiently, the dimensioned cores are ready for the finishing

planer. If desired, they may be planed while still warm. There is no danger of sunken joints appearing later for the resin glue is very low in water content and the joint is set under steam heat which rapidly vaporizes excess glue moisture.

Automatic lumber presses are steam heated because it is essential that they be kept clean. If high frequency heating were used, the electrodes would gum up and interfere with proper operation. Steam platens, on the other hand, keep the machine clean automatically because the squeezed out resin will not stick to the hot metal.

New Developments in Edge Gluing

A 1948 development, which was planned for several years, was the placing into operation of an automatic lumber press equipped with high frequency heating behind the steam platens. This is a standard steam heated machine from which one of three lower steam platens was removed. In its place was installed an insulated electrode. This was the so-called "hot" electrode. The balance of the machine was the other or ground electrode. Thus, the lumber is first heated by the steam platens. This cures the squeezed-out and also a portion of the glue in the joint. When the stock then moves over the "hot" electrode, the balance of the glue is cured almost instantly.

This combination machine has been run at speeds as high as 20 lineal feet per minute. Obviously, it is so fast that only relatively wide stock can keep up with it.

The lumber cutting and gluing methods described are today becoming the standard operating procedure in the most modern and progressive furniture and woodworking plants.

FOREST PRODUCTS RESEARCH SOCIETY

Experiments in Rotary Veneer Cutting*

H. O. Fleischer

Technologist, Forest Products Laboratory,[1] Forest Service, U. S. Department of Agriculture

This paper summarizes the results of an extensive series of tests on a number of woods to determine the effect of several major variables in the rotary veneer-cutting process on the quality of veneer produced. Variables studied under knife angle adjustment were: veneer thickness, effect of species, and log diameter. The effect of vertical and horizontal opening of the nosebar also was studied. The cutting action of the knife and quality of veneer produced under several conditions of knife angle and nosebar pressure are illustrated. A number of general principles relating to factors affecting veneer quality are discussed and guides to quality production are given.

Introduction

THE term "veneer" is used to describe relatively large, thin sheets of wood used to make plywood, containers, furniture surfaces, battery separators, porch shades, and many other products. Most veneer is cut on a lathe by the rotary process; that is, the log is revolved against a knife and the veneer comes from it in a continuous sheet, much as paper is unrolled. Some veneer is also cut by a slicing process, in which the log is moved across the knife and the veneer is obtained in relatively narrow sheets. To a limited extent veneer is also cut on a saw by a process similar to sawing lumber *(5)*.

This report deals with Forest Products Laboratory experiments designed to study certain variable factors in the rotary veneer-cutting process, such as the angle of the knife in relation to the log and the role of the nosebar in applying pressure to the wood during cutting. Although the work was performed entirely on a rotary lathe, some of the results may have application also in connection with veneer slicers, since the slicing process is basically similar to the rotary-cutting process.

Description of the Rotary-Cutting Process and of Terms in Common Use

The most important parts of the rotary lathe, with respect to controlling the quality of the cutting, are the knife and the nosebar *(3)*. These are mounted in a carriage that moves ahead a distance equal to the thickness of the veneer being cut each time that the bolt revolves once in the lathe. Fig. 1 shows a rotary lathe in operation, with the veneer being wound on a drum as it comes from the knife. Fig. 2 shows an enlarged view of the knife, the veneer, and the nosebar in their relative positions during an actual cutting operation.

As the veneer is cut it must bend sharply because of the wedging action of the knife. The angle to which the knife is ground must therefore be kept as acute as possible, the minimum being that required to provide sufficient support for its edge and to prevent undue deflection and breakage.

The knife is generally set in the lathe with its edge horizontally in line with the centers of the spindles that support the bolt, and with its face, or ground side, approximately vertical and tangent to the bolt at the point of cutting. The wood generally is somewhat compressed at this point, and there is a certain amount of rubbing or "bearing" of the wood on the face of the knife, as shown in Fig. 2. On the back, or flat side, of the knife, on the other hand, there is also a great deal of bearing, down to a point where the veneer leaves the knife surface to pass out of the lathe.

Because the wood is bent at the knife edge it has a tendency to break or split. The characteristic breaks are known as "lathe checks", and always extend inward from the under side, or "loose side", of the veneer (Fig. 2). The opposite side of the veneer sheet is known as the "tight side" and is the surface that is generally exposed in the plywood panel, except when a part of the face veneer is reversed for the matching of grain or figure. Veneer that is relatively free from lathe checks is spoken of as "tight" or "firm".

The conventional nosebar is ground at a blunt angle and may be kept relatively sharp

* Presented by title only.

[1] Maintained at Madison, Wisconsin, in cooperation with the University of Wisconsin.

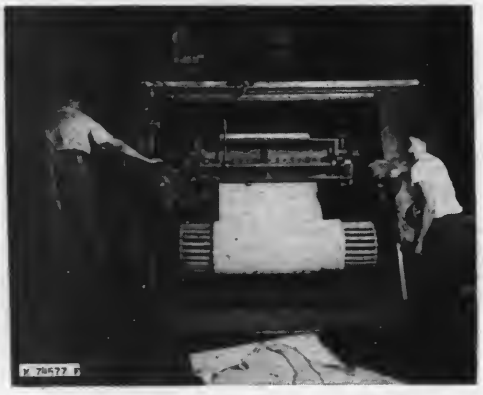


Fig. 1.—The Forest Products Laboratory veneer lathe in operation.

or may be allowed to become quite rounded at the tip. Some lathes are equipped with roller nosebars. The nosebar is intended to apply a compressive force to the outer surface of the bolt, just above the edge of the knife. The functions of the nosebar are to guide the knife in its true position with relation to the outer surface of the log, to compress the wood ahead of the knife and thus keep it from splitting ahead of the knife, and to compress the wood sufficiently at and slightly below the point of cutting so that lathe checks are not excessive *(2)*.

The control of cutting, as reflected in the quality of the veneer, involves the maintenance of uniformly true thicknesses as the cutting progresses, smoothness of the surfaces, and "tightness", or freedom from excessive lathe checking. Care must also be taken that the wood is not overcompressed to the point where it fails to recover to its proper thickness after cutting, and that it is not ruptured during cutting along the plane between the springwood and summerwood, or injured in other ways. The quality of the veneer may be affected by a great many factors, including the type and condition of the wood, the condition of the lathe, and the manner in which the various knife and nosebar adjustments are made.

Experimental Procedure

Various native species of wood have been cut experimentally into veneer at the Forest Products Laboratory, over a period of years. Although the primary objective of much of this work has been to determine the suitability of certain species for veneer cutting or to produce veneer for test purposes, it has nevertheless afforded opportunity to accumulate considerable data on cutting variables.

Before adequate records could be kept, it was necessary to develop ways and means of measuring and recording the various settings conveniently, since there are no generally accepted standard means of doing this. The terminology used is illustrated diagrammatically in Fig. 3.

The lathe knives used for most of these studies had hardened tool-steel edge inserts of medium temper and were carefully ground and honed. Each knife was 5/8 inch thick, ground to a bevel such that the width of its ground face was 1-13/16 inches. The angle of the bevel was then 20 degrees, 10 minutes. The grinding was done with a cup-shaped wheel so set as to provide a concave surface with a maximum depression of 0.002 inch. When first positioned in the carriage, the knife was adjusted so that its edge was horizontally in line with the spindle centers and its face was truly vertical when measured with a hand level held vertically against it and touching it at its tip and its heel. The angle referred to in Fig. 3 as the "knife angle" was then 90 degrees.

During the course of the cutting the carriage could be tilted in such a way that the knife angle changed, and often it varied as much as 2 degrees above or below 90 degrees, during the course of a single experimental run. Once the knife was properly set up, its position could be quickly determined by means of a vernier scale attached to the carriage, as shown in Fig. 4, which indicated the knife angle directly. The lathe was also equipped with an arrangement that provided for a certain amount of change automatically in the knife angle. In most of the studies, however, this automatic feature was not used; to maintain constant control of knife angles, the adjustments were in most cases made by hand as the need for them became evident.

The nosebar used was a rigid steel bar with its front edge generally ground at an angle of 15 degrees from a vertical plane (Fig. 3). When the nosebar was first mounted in the

Fig. 2.—Enlarged view of the position of the knife, *a*, the nosebar, *b*, and the veneer, *c*, in an actual rotary veneer-cutting operation. Approximately four times natural size, showing lathe checks, *d*, face of knife, *e*, and back of knife, *f*.

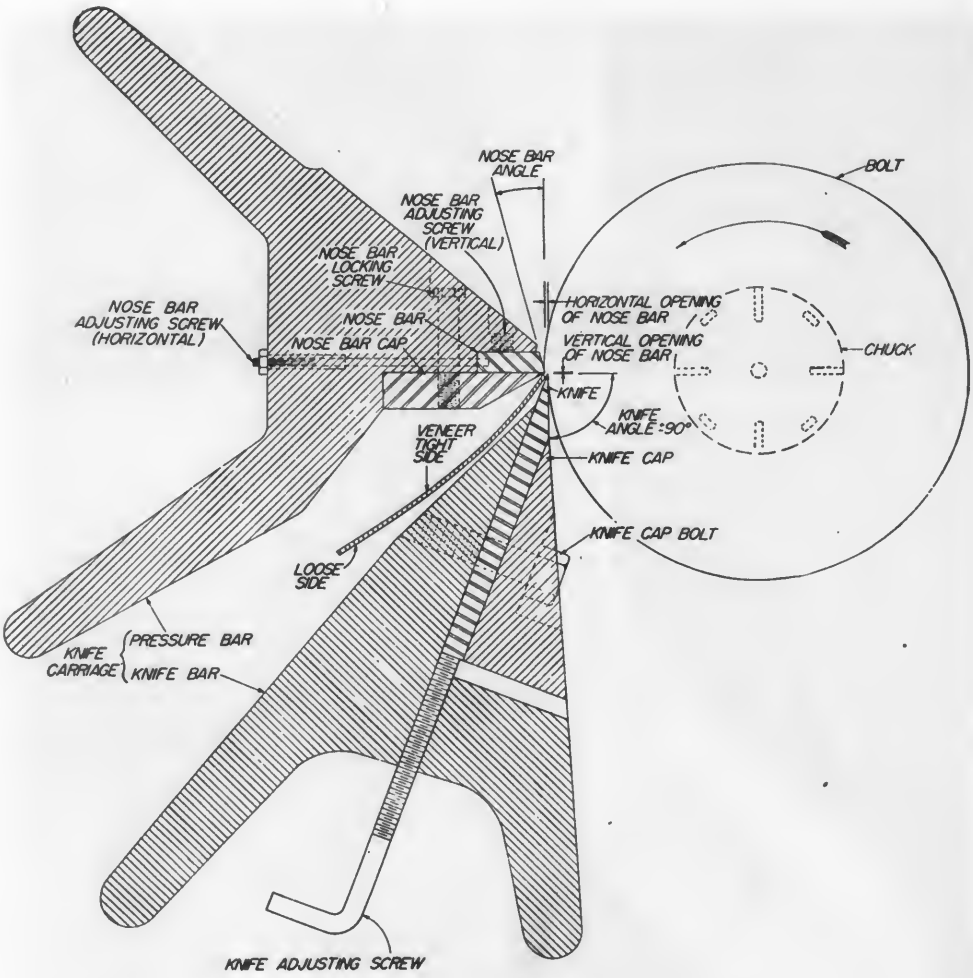


Fig. 3.—Diagram showing cross section of lathe carriage and veneer bolt, and illustrating the terminology used.

lathe it was set only a limited distance above the knife edge, and alined with it by sight and touch. This truing-up operation is the most critical one in setting up the lathe, and must be done in such a way that the knife and nosebar are in true alinement along the entire cutting length *(2), (3), (4)*. Sometimes, during the cutting, readjustments were necessary to provide for thermal expansion that had occurred in the parts.

Both the vertical distance and the horizontal distance between the lower tip of the nosebar and the edge of the knife, known respectively as the "vertical bar opening" and the "horizontal bar opening" (Fig. 3), varied according to the cutting. To permit rapid measurement of the horizontal opening on the lathe, an indicating needle was attached to the screw that moved the pressure bar horizontally in relation to the knife bar; the needle was set at zero

Fig. 4.—Reading knife angle on vernier scale of experimental veneer-cutting lathe.

when the knife and nosebar were first put in the lathe and when the nosebar edge was in true alinement with and adjacent to the knife edge. Thereafter, as the nosebar was adjusted, its position in relation to the knife could be read directly from the needle (Fig. 5).

Ordinarily, the speed at which the veneer comes from the lathe varies somewhat as the diameter of the bolt in the lathe decreases. In laboratory studies an attempt was made to maintain the speed within a limited range. Although no instruments were regularly used to check the speed, an occasional check was made with a tachometer. In general, a speed of about 125 to 150 feet (linear) per minute was maintained.

Fig. 5.—Needle attached to screw that moves pressure bar horizontally, indicating relative position of bar with respect to knife edge.

Size and Scope of the Studies

Records have been kept at the Forest Products Laboratory on the cutting of approximately 1,300 veneer bolts.[2] Approximately 800 of these were yellow birch, 150 were yellow-poplar, 70 were sweetgum, 50 were Douglas-fir, and the remainder were of other species represented in smaller numbers. About 560 bolts were cut into 1/16-inch veneer, 320 into 1/8-inch veneer, 95 into 1/32-inch veneer, 80 into 1/100-inch veneer, and the remainder into various other thicknesses up to 5/16 inch.

Records were made of the temperature at which the bolts were heated, the bevel and condition of the knife and the nosebar, the settings of the knife and the nosebar, and other factors peculiar to the species. The initial work on a species generally involved investigation of the species variables to determine the conditions required for optimum veneer production. On some species, such as birch, where much veneer was required for various testing programs in the Laboratory, opportunity existed to check the early conclusions on a large volume of material.

This report covers only the major variables pertaining to the lathe operation itself. It does not include such other aspects of the problem as the effect of the temperature of the wood, its moisture content, its density, and other factors. The subject of heating veneer logs to prepare them for cutting has been covered in a previous paper *(1)*.

Generally the majority of bolts of any species were cut at what was found to be the optimum cutting temperature, and the results discussed here refer in most cases to material cut in this condition. Yellow birch logs, for example, were regularly heated in water, first at 120° F. for a period of about 24 hours, then at 160° F. for a period of 16 hours or longer. In most cases, with bolts averaging about 20

[2] The early work reported here was done by Don Brouse and Lincoln A. Mueller.

inches in diameter, those portions of the yellow birch bolts under consideration here were within 10° to 15° of 160° F.

The results discussed in this report, unless otherwise stated, apply to bolts that were 12 to 20 inches in diameter, or to portions of bolts between these diameters.

Evaluation and Variability of Results

The most difficult aspect of the experimental work lay in the evaluation of the results obtained. At present there are no simple, easily applied, objective standards for measuring the quality of veneer. The two quality factors that vary most readily as the lathe settings are changed are the tightness, or degree of freedom from lathe checking, and the smoothness of the veneer. The cutting quality obtained was therefore evaluated subjectively and described by means of such terms as "tight" or "loose" and "rough" or "smooth". It is readily apparent that there is certain to be a great deal of variation in the results due to the human factor, especially since the results were collected over a period of years and by different people.

The other most important source of variability lies in the material under study. Bolts of the same species vary in diameter, density, hardness, and moisture content; bolts of different species display a variety of structural features ranging from microscopic differences in cell structure to coarse differences in grain pattern. The problem of isolating a single variable factor, such as knife angle, and drawing conclusions that will be applicable to a wide range of species thus becomes difficult.

Consequently, the results presented in this report are tentative in character and may be modified as further work is done and more accurate methods of measuring veneer quality are developed.

Results

Knife-Angle Adjustments

The effects of angle adjustments. For each species and thickness of veneer cut, records were kept of what appeared to be the most suitable knife angles for producing smooth and uniformly thick veneer. Fig. 6 is a graphic summary of results obtained in a large number of tests on a number of species. For 1/8-inch veneer, knife-angle settings varying from 89 degrees, 30 minutes to 90 degrees, 30 minutes, according to the species, were found to be most satisfactory. For 1/16-inch veneer, the most satisfactory angles lay between 89 degrees, 40 minutes, and 91 degrees, 15 minutes, and for 1/100-inch veneer they lay between 90 degrees, 50 minutes, and 92 degrees, 30 minutes. The graph shows a definite trend toward higher knife angles as the veneer thicknesses decrease.

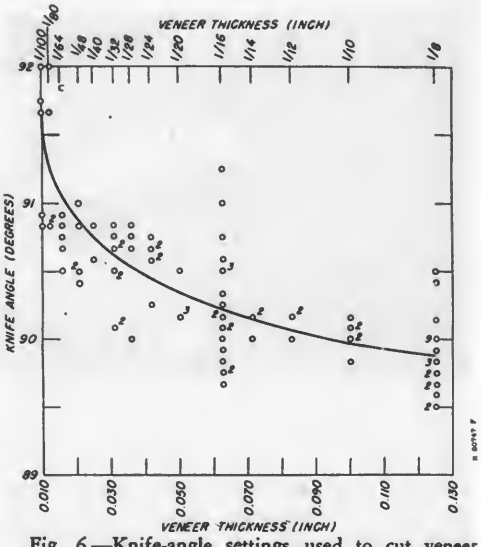


Fig. 6.—Knife-angle settings used to cut veneer of 22 species in various thicknesses. Each species is represented only once for each thickness of veneer. Numerals indicate superimposed points.

When cutting veneer with a knife angle setting that was too low, or, in terms of the trade, when there was "too much bearing" on the face of the knife, the veneer produced varied in thickness in waves that were several feet long. For example, for 1/8-inch birch veneer a knife angle of 90 degrees, 0 minutes resulted in veneer of uniform thickness, but adjusting the knife to a lower angle of 88 degrees, 30 minutes might result in wavy veneer in which the thickness might be as much as 0.005 inch over and under the desired thickness. When cutting thinner birch veneer, such as 1/32-inch, lowering the knife angle from a satisfactory one of 90 degrees, 50 minutes to 90 degrees, 0 minutes at times resulted in veneer that varied in thickness from paper-thin to about twice the desired thickness. When cutting very thin veneer, such as 1/64- or 1/100-inch, the knife sometimes cut out of the wood

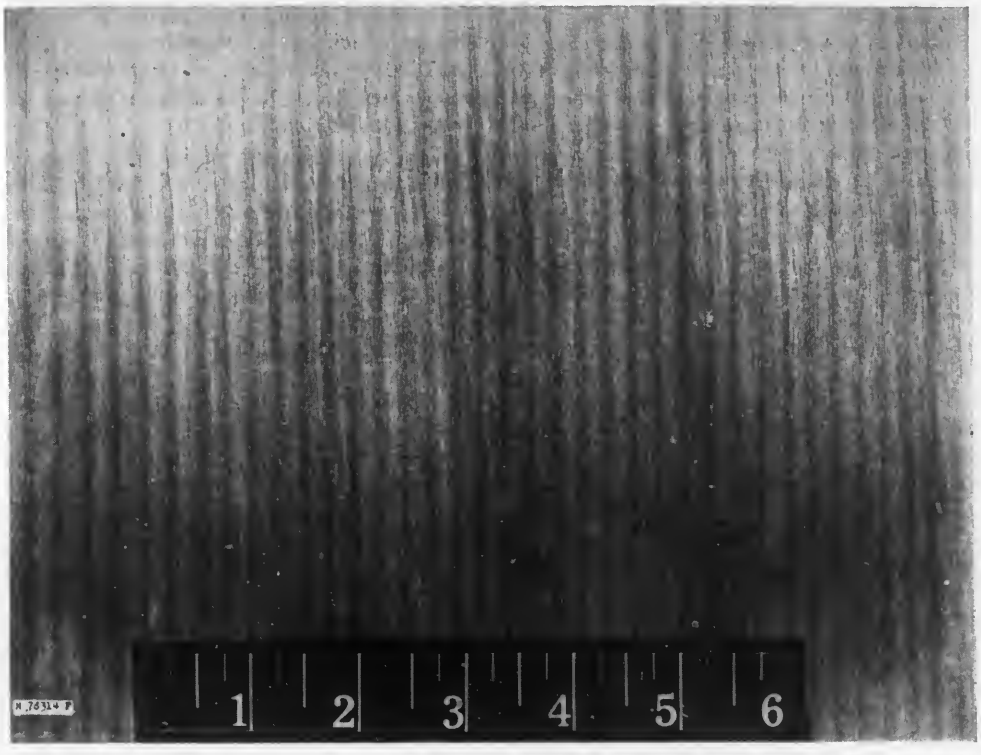


Fig. 7.—Yellow birch ⅛-inch veneer cut with a knife-angle setting of 91 degrees, 50 minutes (too much "lead"), displaying pronounced corrugations.

entirely, unless its angle was increased sufficiently to overcome this tendency.

On the other hand, as the knife angle for a given thickness of veneer of a particular species was increased, a limit was soon reached beyond which a further increase, or more "lead" of the knife into the wood, resulted in corrugated veneer. In this veneer the waves were very short, generally only ¼ to ⅜ inch from crest to crest, and apparently resulted from a rhythmic vibration of the knife edge (Fig. 7). It was probably brought about because the knife, which acts as a wedge, had a tendency to dig into the wood when tilted too far; therefore it alternately dug in and sprang back to its normal position. The difference in thickness of the veneer, between adjacent crest and trough, sometimes was so slight as to be unmeasurable with commonly used instruments, but in other cases was observed to be up to 0.004 inch.

That the corrugated surface was caused by the action of the knife, rather than by the nosebar, was shown by the fact that when a pronounced corrugated pattern was formed on the veneer, it was also observable to the same pronounced degree on the surface of the veneer bolt in the lathe. Furthermore, it was often observed that the pattern of waves on the bark side of the veneer was not exactly superimposed over the pattern on the pith side, and the veneer did not always vary in thickness as much as was indicated by a visual examination of one surface only.

Pronounced corrugating produced by a knife angle that is too high is easier to detect by eye than waviness produced when the angle is too low. For this reason, apparently, many lathe operators prefer, when adjusting the knife to cut a certain thickness of veneer, to adjust the angle upward to a point where wash-

boarding first begins to appear, then to decrease it slightly and proceed to cut *(3)*.

Within the limits bounded on one side by the angle at which corrugating occurred and on the other by the angle at which wavy veneer occurred, there was sometimes a relatively wide range of angles throughout which veneer of uniform thickness could be cut. This was particularly true for the thicker veneer, such as ⅛ inch, whereas for very thin veneer, such as 1/100-inch yellow birch, the range might be only 15 to 30 minutes. Within this range the effect of varying the knife angle was not very pronounced on birch nor on other species, and was noticeable chiefly on the smoothness. On softwoods, minute differences in smoothness were often impossible to detect visually; on hardwoods, and especially on such uniform-textured hardwoods as birch, slight tendencies for the fibers to "pick out"—that is, tear rather than cut smoothly—could often be overcome by lowering the knife angle as little as 5 or 10 minutes. This roughness due to torn-out fibers was particularly pronounced in areas of irregular or sloping grain, and in these cases could sometimes be overcome or diminished by decreasing the angle by as much as 20 or 30 minutes, or as far as possible without encountering wavy veneer.

Effect of veneer thickness.—It has been mentioned above that knife-angle settings between 89 degrees, 30 minutes and 90 degrees, 30 minutes were suitable for cutting excellent veneer of ⅛-inch thickness, whereas, as the thickness of the veneer decreased, these angles had to be increased (Fig. 6). In the terminology of the lathe operator, the "bearing" on the face of the knife had to decrease with the veneer thickness. Thus for ⅛-inch birch veneer the angle that generally gave satisfactory veneer was 90 degrees, for 1/16-inch it was 90 degrees, 20 minutes; for 1/32-inch veneer it was 90 degrees, 50 minutes; for 1/64-inch veneer it was 91 degrees, 30 minutes; and for 1/100-inch veneer it was 92 degrees, 30 minutes (Fig. 8A).

Effect of species.—When working with a variety of species the results obtained were complicated not only because of differences in density, grain pattern, etc., but because the logs of the different species varied in diameters and in optimum cutting temperatures. In spite of the great number of variables involved, for which there was no way of compensating, the results obtained with the different species followed similar trends.

Fig. 6 has already shown that, when all species cut were considered together, a definite inverse relation between knife angles and veneer thicknesses became evident. In Fig. 8 the knife angles used to cut satisfactory veneer of various thicknesses are individually plotted for six representative species. The logs of each species were heated according to what was considered a proper schedule for the particular species.[3]

In every case the inverse relationship previously pointed out existed, but between the species there were some differences in the slopes of the curves. The curve for yellow birch (Fig. 8) has already been described. For the two softwoods shown in Fig. 8, Douglas fir and Sitka spruce, the curves representing knife angles were similar to that for birch. In the case of the other two native hardwoods represented, sweetgum and yellow-poplar, the upward trends of the curves for thinner veneers were less pronounced. Sweetgum veneer 1/100 inch thick was cut satisfactorily with a knife angle of 91 degrees, 40 minutes, and for yellow-poplar the comparable figure was only 90 degrees, 50 minutes. Among hardwoods of uniform texture the variation in the shapes of the curves might indicate a relation to wood density. Among woods of lesser density, such as yellow-poplar, it was not necessary to increase the knife angle sharply as the veneer thickness dropped below 1/32 inch. The reason for this may be that the stresses that tend to deflect the knife edge and cause it to cut wavy veneer are not so great with the less dense woods as they are with woods of greater density.

Not all species included in the veneer studies at the Forest Products Laboratory were cut into a great variety of veneer thicknesses. In some cases the work was limited to only two or three thicknesses, and sometimes not enough material was available to investigate

[3] The final temperatures attained in the vat for heating the species shown in Fig. 8 were: yellow birch, 160° F.; Douglas fir, 180° F.; Sitka spruce, unheated (cut at room temperature); sweetgum, 150° F.; yellow-poplar, 120° F.; and khaya, 180° F.

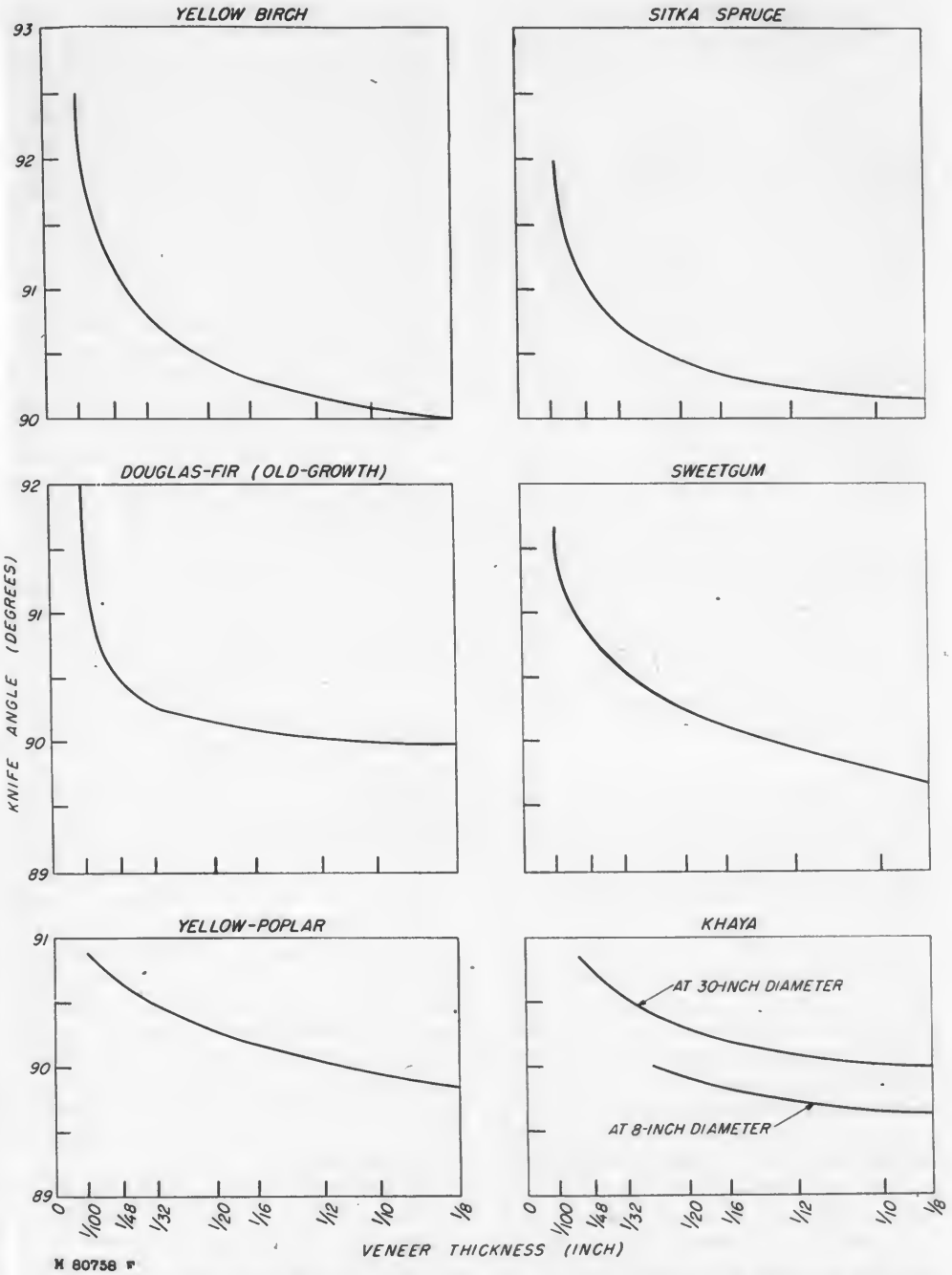


Fig. 8.—Knife angle used to cut various thicknesses of veneer of a number of representative species. The log diameters were 12 to 20 inches, except for khaya, where two curves for diameters of 30 and 8 inches are given.

TABLE 1.—KNIFE ANGLES USED TO CUT 1/16- AND 1/8-INCH VENEER OF VARIOUS SPECIES, WHEN LOG DIAMETERS WERE 12 TO 20 INCHES

Species	Knife angle	
	1/16-inch veneer	1/8-inch veneer
Aspen, quaking	90°—30′	90°—00′
Birch, yellow	90°—20′	90°—00′
Cottonwood	90°—00′	89°—40′
Douglas fir (old-growth)	90°—05′	90°—00′
Fir, white	-- --	89°—50′
Fir, California red	-- --	89°—50′
Fir, silver	-- --	90°—00′
Hemlock, western	90°—45′	90°—00′
Khaya	90°—00′	89°—45′
Larch, western	91°—15′	89°—55′
Maple, sugar	90°—10′	90°—00′
Oak, California black	-- --	90°—25′
Oak, water (from Louisiana)	90°—15′	90°—00′
Oak, water (from Alabama)	89°—50′	89°—30′
Oak, white	90°—30′	90°—00′
Pine, Arizona	91°—00′	90°—30′
Pine, Ponderosa	89°—40′	89°—35′
Pine, Western white	89°—55′	89°—45′
Spruce, Engelmann	89°—45′	89°—30′
Spruce, Sitka	90°—35′	90°—10′
Sweetgum	90°—05′	89°—40′
Tanoak	90°—30′	89°—45′
Yellow-poplar	90°—10′	89°—50′

thoroughly the effects of varying the knife angles over a wide range. Table 1, however, is a tabulation of the knife angles that gave satisfactory results when cutting 1/16- and 1/8-inch veneer of various species. The log diameters involved were from 12 to 20 inches, and in every case the logs were heated at the temperatures that were considered the optimum for the species.

The effect of log diameter.—It has often been said that as the diameter of the log decreases the angle of the knife must also decrease in order that "a constant bearing be kept on the knife".*(2)* It can readily be seen from Fig. 3 that if the knife angle remains exactly at 90 degrees as illustrated, but the diameter of the log decreases, the width of the strip of wood that bears on the ground surface of the knife, referred to as the "bearing on the knife", will decrease (other settings remaining constant). As it decreases there may be a rearrangement of the stresses that affect the knife edge, and a condition may eventually arise similar to that occurring when the knife is tilted too far into the log. In other words, the stresses tending to deflect the knife edge inward overbalance those tending to force it outward, the knife edge may begin to chatter, and corrugated veneer may result. In accordance with this theory, some lathes have been designed to provide for an automatic adjustment to decrease the knife angle as the carriage moves inward and the diameter of the bolt being cut becomes smaller. The design may be such that the adjustment goes on automatically at such a rate that the bearing on the knife will remain constant throughout, provided no other manual adjustments are made.

Experiments at the Forest Products Laboratory have also indicated that, as the diameters of the bolts in the lathe decrease, it is often necessary to decrease the knife angle. On yellow birch, for example, an angle setting that was satisfactory at a 20-inch diameter occasionally resulted in some roughness over areas of irregular grain, or even in corrugated veneer, by the time the diameter of the bolt had dropped to less than 12 inches. On 1/16-inch birch veneer a reduction of the knife angle as the cutting progressed by 5 minutes (or from the setting of 90 degrees, 20 minutes shown in Fig. 8 to a setting of 90 degrees, 15 minutes) was generally found sufficient to produce good veneer at the lesser diameters. In cutting 1/8-inch birch veneer, such an adjustment generally was not necessary. On 1/100-inch veneer, on the other hand, the angle had to be reduced in some cases from 92 degrees, 30 minutes as shown in Fig. 8 to as low as 91 degrees at a 6-inch core, in order to maintain good cutting throughout.

Experiments on khaya logs heated in water at 180° F. and cut into veneer of various thicknesses illustrated this effect in more pronounced manner, since the logs were of larger diameter than the birch logs. The results are summarized in Fig. 8. Two knife-angle curves were developed, one showing the settings found suitable for various thicknesses of veneer when the cutting commenced and the log diameters were 28 to 32 inches, the other showing the settings when the logs had been cut down to 8-inch diameters. The latter curve would seem to follow approximately the same pattern as the former, but lay about 20 to 25 minutes of a degree below it.

Mathematical analysis showed that, if the knife were set at the proper angle so that a bearing of 1/10 inch were obtained on the ground surface of the knife at a diameter of 30 inches, this angle would have to be dropped by about 30 minutes in order to retain this 1/10-inch bearing at a diameter of 8 inches.

Other knife-angle variables.—Veneer bolts of certain species are often heated in order to soften the wood and to facilitate the cutting. Various amounts of heating may result in different stages of softness. It is possible, therefore, that bolts of the same species heated to different temperatures might cut best at different knife angles. To date, however, experiments have failed to show that this factor has a pronounced effect.

In one case, for example, a series of five veneer bolts from a single yellow birch log were cut into 1/16-inch veneer after being heated at a variety of temperatures, from room temperature (80° F.) to 180° F. As each bolt was cut, certain predetermined lathe adjustments were systematically made. In this experiment the smoothest veneer was cut in every case, with knife-angle settings of 90 degrees to 90 degrees, 30 minutes. In every case, regardless of temperature, slight traces of corrugating began to appear between 90 degrees, 30 minutes and 91 degrees. There was some indication that the corrugating was more pronounced on the veneer cut from the bolts that were at the lower temperatures, but the effect was not pronounced.

Other factors, not considered in this report may have some effect on the optimum knife-angle settings. Some of these may be the bevel to which the knife is ground, whether or not the knife is back-bevelled, and the speed of cutting.

Nosebar Settings

For a thorough study of nosebar settings it would be desirable to measure actual pressures applied to the wood as well as the power consumption while the cutting was progressing. To date, however, such measurements have not been made, and the amount of pressure applied by the nosebar has been measured only in terms of the opening between the knife edge and the nosebar edge.

The vertical opening of the nosebar.—After a limited number of exploratory tests it was found that suitable cutting could be obtained in most cases by varying the vertical opening of the bar approximately according to the thickness of the veneer, from a low of 0.005 inch for 1/100-inch veneer to a high of 0.030 inch (almost 1/32 inch) for veneer 1/8 inch thick. This relationship is illustrated in Fig. 9. No systematic study was made of the effect of deviations from this rule of thumb.

In isolated instances a certain amount of roughness occurred in yellow birch veneer that was attributed to setting the bar too high, so that there was some opportunity for the fibers to split or tear out of the surface ahead of the knife. Reducing the nosebar opening to 0.025 inch for 1/8-inch veneer, and correspondingly for some other thicknesses, seemed to improve the smoothness of the veneer.

Horizontal opening of nosebar.—In discussing horizontal nosebar openings, it must be kept in mind that the vertical opening varied according to the thickness of the veneer being cut, as shown in Fig. 9. If the vertical opening varied greatly from that shown, some change would also be warranted in the horizontal opening, since the degree of effective

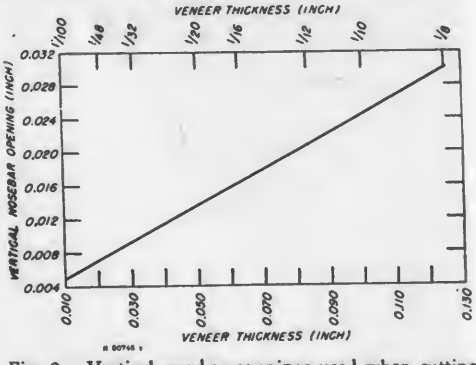


Fig. 9.—Vertical nosebar openings used when cutting various thicknesses of veneer.

pressure on the wood is a function of both the horizontal and the vertical components.

Limited experiments demonstrated that, when the nosebar was withdrawn to the point where no pressure was applied, the veneer was often rough and generally contained severe lathe checks. When the opening between the knife and the nosebar was progressively reduced, the compression eventually became so great as to damage the wood, even though lathe checking might have been eliminated and the veneer made much smoother. Gross overcompression could be detected by thickness measurements on the veneer. Thus, when cutting nominal 1/16-inch birch with a horizontal opening of 0.040 inch, average veneer thick-

Fig. 10.—Cutting $\frac{1}{28}$-inch yellow birch veneer with several different nosebar settings. A, without nosebar pressure the lathe checks and the roughness of the surfaces are pronounced.

Fig. 10B.—With an opening of 0.290 inch (93 percent of the veneer thickness) the veneer was relatively smooth and the lathe checks were less pronounced.

Fig. 10C.—With an opening of 0.270 inch (86 percent of the veneer thickness) the tightness and smoothness were excellent but the wood was overcompressed.

ness (green, shortly after cutting) was only 0.045 inch instead of 0.0625 inch; nominal 1/8-inch birch cut with an opening of 0.080 inch was only 0.113 inch thick instead of 0.125 inch. These figures indicate that, in these cases, the veneer had been compressed beyond the point of recovery and that a permanent deformation of the wood fibers might have taken place.

Within the range of nosebar settings up to the point where overcompression occurred, it appeared that increasing pressure resulted not only in greater tightness but also in greater smoothness of the veneer. Both of these effects are illustrated in Fig. 10 for three nosebar settings used while cutting 5/16-inch (0.3125-inch) yellow birch veneer. When no pressure was applied the veneer had very pronounced lathe checks and its surfaces were rough (Fig. 10, *A*). When the bar was moved ahead so that the horizontal opening was only 0.290 inch, checking was less severe and the veneer was relatively smooth (Fig. 10, *B*). When a still higher pressure was applied to the veneer, with a horizontal setting of 0.270 inch, the lathe checks were almost completely eliminated and the veneer was smooth (Fig. 10, *C*). In the last case the thickness of the veneer was reduced slightly because of overcompression. Within the range of bar pressures studied at the Forest Products Laboratory, increasing nosebar pressure regularly resulted in increasing tightness, if other settings were held constant; the effect on smoothness was not always so marked and regular, but was most pronounced in the lower range of pressures. The degree of tightness and smoothness, however, may also be markedly affected by the tempera-

Fig. 11.—Western hemlock veneer 1/8-inch thick, showing variations in quality obtained with horizontal nosebar openings of (from left to right) 8/64 (A), 7/64 (B), 6/64 (C), and 5/64 (D) inch.

ture of the wood at the time of cutting and by other factors such as the sharpness of the knife.

The effect of varying the nosebar setting when cutting a softwood veneer is illustrated with Western hemlock in Fig. 11. When no pressure was applied during cutting, the surface of the veneer was very rough (Fig. 11, *A*) and the lathe checks were very pronounced. Moderate pressures gave increased smoothness Figs. 11, *B* and *C*) and reduced the severity of the lathe checks. The pressure applied when the horizontal opening was 6/64 inch, or 75 percent of the veneer thickness, gave the best results in this case. A very high pressure with a nosebar opening of 5/64 inch damaged the wood in a way called "shelling" (Fig. 11, *D*) which became apparent immediately. Shelling can be described as the loosening of thin slivers or sections of veneer from the surface, with the separation occurring at the zone between the springwood and the summerwood. Apparently it occurs because overcompression crushes the thin, earlywood cells. The defect is most frequently encountered in softwoods, and may not become apparent until the veneer has been dried, or even until it is made into plywood. Shelling is less likely to occur in wood that has been properly softened for cutting by heating than in wood that is unheated.

From the above it is apparent that thin veneer can be cut without damage under higher compression, percentagewise of its thickness, than can thick veneer. For example, when cutting 1/16-inch birch veneer, overcompression occurred when the horizontal nosebar opening was 64 percent of the veneer thickness; when cutting 5/16-inch birch veneer it occurred at 86 percent. Because of the concentration of stresses in the wood at the tip of the nosebar, it is reasonable to assume that a damaging overcompression of the surface fibers may occur as soon as the bar has penetrated the wood to a certain absolute depth, regardless of the veneer thickness. On the other hand, if measured in terms of veneer thickness, 75 percent compression would require, in the case of 1/8-inch veneer, that the nosebar compress the wood to twice the depth required to obtain a compression of 75 percent in the case of 1/16-inch veneer. Lathe checking is more easily controlled, by applying adequate nosebar pressures, without danger of damaging the wood, when cutting thin veneer, therefore, than when cutting thicker veneer.

The application of adequate pressures in cutting thicker veneer requires the utmost skill and judgment on the part of the lathe operator. The more pressure applied, the more power consumed in cutting, and the greater are the stresses that are applied to the log ends, the spindles, and the bearings of the lathe. Experience has also shown that the more the wood is compressed, the more readily do slight inaccuracies in lining up the knife and the nosebar result in irregularities on the surface of the bolt that, if not corrected, grow with each revolution until the bolt assumes a "barrel shape" or develops circumferential ridges that gradually become so pronounced that cutting must stop.

For a similar reason grain irregularities, such as the distortions occurring around knots, also sometimes caused difficulty. Because of partial end grain at these points, the wood was not so readily compressed by the nosebar, the veneer was thin, and an excess of wood was built up on the bolt surface. On logs having a fairly regular grain, however, it was possible to apply high nosebar pressures and yet avoid these difficulties by careful adjustment of knife and nosebar and occasional readjustments after the lathe parts had heated up.

Rounding the leading edge of the nosebar on a 1/8-inch radius, in preference to grinding it to a sharp edge, was studied in connection with the cutting of Western hemlock. In this case the bar was also ground at a 12 degree angle instead of 15 degree (Fig. 3). The use of this rounded bar did not seem to improve the smoothness of the veneer. In commercial use it would probably be disadvantageous because, the blunter the bar, the more wood needs to be compressed to get the same degree of compression at the desired point. Since compression is difficult to gage, it is likely that the lathe operator, in setting the bar by "feel", might often attain less compression and consequently a poorer quality of veneer than with a sharp-edged bar.

Conclusions

The quality of rotary-cut veneer, as evidenced chiefly by its smoothness and tightness, is appreciably affected by the settings or adjustments of two parts of the lathe, the knife and the nosebar.

For ⅛-inch veneer of birch and many other species, a knife-angle setting of 90 degrees—the setup obtained when the ground surface of the knife is in a vertical plane as evidenced by a level held vertically against it—or within 30 minutes plus or minus from this figure, was found to be suitable for the production of satisfactory veneer. Angle settings lower than this—that is, when the "bearing" on the knife surface increased—resulted in veneer that was wavy or nonuniform in thickness. Settings higher than this—that is, when the "lead" of the knife was increased—resulted in corrugated veneer. Within limits between these two extremes, angle adjustments were sometimes effective in improving the smoothness of the veneer surface.

When veneer thinner than ⅛ inch was cut, the knife angles used to produce satisfactory veneer became progressively higher. This relationship between knife angle and veneer thickness was graphically demonstrated by plotting the angle settings used to cut veneers of various species over the veneer thicknesses.

With thin veneer, such as 1/64- or 1/100-inch, the knife angles had to be increased much more with such species as yellow birch than with others, such as yellow-poplar. This may indicate a relationship, at least among the uniform-textured hardwoods, between knife angle and wood density. In some cases the knife angle had to be decreased as the diameter of the log decreased while being cut. This effect was noticeable chiefly on logs of large diameter, and was more pronounced when cutting thin veneer than thick veneer, because the thin material required more critical adjustment of knife angles. The temperature of the wood at the time of cutting did not seem to affect the knife angle pronouncedly.

Reduction of the horizontal opening between the tip of the nosebar and the tip of the knife, up to the point where overcompression resulted in a reduction in the thickness of the veneer being cut, was effective in reducing both the severity of lathe checks and the roughness of the veneer. Excessive compression in the case of some softwoods resulted in shelling, or slivering, due to a separation between the springwood and the summerwood. When heavy nosebar pressures were applied, it was important that the various adjustments required to cut good veneer be accurately made, as any inaccuracies in settings promptly showed up in the cutting. Rounding the leading edge of the nosebar was not effective in improving the quality of the veneer produced.

It is thought that there are definite relationships between the various parts of the lathe that affect the cutting quality. The conclusions drawn here may be valid only if the various factors are considered and certain variables are held constant, such as the bevel of the knife, the degree of hollow grinding of the knife, and the bevel of the nosebar. In order to duplicate the actual settings discussed above and to obtain comparable results, it would also be necessary to have the lathe in excellent condition, with no loose or worn parts to permit unwarranted movement, and the knife and nosebar in good condition.

Literature Cited

(1) Fleischer, H. O. Heating Veneer Logs. Wood, Vol. 3, No. 3. 1948.
(2) Hyler, J. E. Rotary Lathe Pressurebars. Veneers and Plywood, Vol. 40, Nos. 4, 5, 6, 7. 1946.
(3) Kessler, L. H. One Veneer Cutter to Another. Plywood Engineering, Nos. 20–40. 1940.
(4) Roberts, John N. and Roberts, John R. Fundamentals of Knife-cutting Veneers. Transactions American Society of Mechanical Engineers WDI–55–4, Vol. 55, No. 8. 1933.
(5) Truax, T. R. The Manufacture of Veneer. Forest Products Laboratory Report No. R285, 6 pp. Illus. 1939.

Discussion

R. K. Stem (Chester B. Stem, Inc.): The points brought out in regard to angle of knife and bar and their relationship to the position of the log have been known to us all only through a trial and error experience and only in a very casual way.

The illustrations both photographic and diagramatic are the best we have seen to demonstrate so clearly just how the veneer is cut from the log and passes through the cap. For a long time we have wanted to have just such a picture as Mr. Fleischer shows in Fig. 2 of the knife engaging the wood and forcing it through the caps. Fig. 3 could well be used by every veneer mill as it gives a most complete diagram of the entire knife and bar setup and the relation to the caps and the log.

In most veneer mills, the cutters and perhaps one or two others are the only ones intimately familiar with the knife and bar setup of a veneer machine. With this clear illustration those concerned with the administration of the veneer mill can also become familiar with these problems and will in all probability be more inclined to see that a scientific approach and a more exhaustive study be made of their own particular veneer cutting procedures.

This paper is the most clear and scientific research approach ever made to the cutting of veneer. It is an indication of what should be done in all of the phases of veneer production. It encourages the writer to feel that a scientific approach can be made to all of our procedures, such as the effects of cutting in all of the species, a study of the qualities most desirable in a veneer knife and bar, such as hardness, angle at which the face should be ground, etc., the drying of various species and thicknesses, etc.

E. P. Morris (The Coe Manufacturing Company): Since the beginning of the veneer industry there has been a need for technical data on rotary cutting of veneers into various thicknesses from different types of logs. To this date many of the important factors have to be learned by trial and error method on the part of the operators with the result that the number of conclusions are almost as many and varied as the operators. Because of the many variables even in blocks from the same tree much less in the many kinds of timber it is doubtful whether it will ever be possible to determine exact and specific recommendations for each and every condition. However, it is possible to establish certain fundamentals and we think that Mr. Fleischer's paper is a splendid beginning in this direction.

James S. Bethel (North Carolina State College of Agriculture and Engineering): The author's study represents the best effort to date at precisely evaluating veneer cutting techniques on a scientific basis. Information of the kind presented is long overdue and its availability should make possible much closer control over the cutting process with an attendant improvement in the uniformity of veneer quality.

The vernier scale used to indicate the knife angle and the needle indicator on the pressure bar adjusting screw should be adaptable to commercial lathe installations. The use of these setting indicators might be particularly valuable where inexperienced operators are being used or when a single lathe set up man must service several machines.

The author explains that the data upon which this study was based were collected incidental to the cutting of veneer for other test purposes which probably explains some gaps which otherwise might have been expected to be filled. Since the type of information presented in this paper is urgently needed by the veneer and plywood industry it may be assumed that the study will be continued and expanded and accordingly some comments on the direction in which such expansion might proceed are perhaps in order. The most obvious addition which might be made to this investigation would be the inclusion of more information on the effect of knife and bar settings on the quality of veneer produced in thicknesses greater than ⅛-inch. Mr. Fleischer indicates in his discussion of the size and scope of the study that data were collected on thicknesses up to 5/16 inch and at one point discusses and illustrates the effects of various nose bar settings on the cutting of 5/16-inch birch veneer. However, the statistical data presented do not extend to veneers thicker than ⅛ inch. Since many of the most critical cutting problems faced by veneer and plywood manufacturers, in the southern hardwood industry at least, involve the cutting of center stock in such thicknesses as 5/32, 1/6 and 3/16 inch statistical data covering these heavier thicknesses would be valuable.

Mr. Fleischer quite properly indicates the present lack of adequate standards for measuring veneer quality. In future expansion of these studies it would appear to be highly desirable to attempt some method of measur-

ing at least the degree of tightness of cut. Some measure of the depth or frequency of lathe checks or their effect on strength reduction might prove suitable and if so would certainly add to the utility of the data.

Other variables whose effect upon uniformity of thickness and tightness and smoothness of cut would be of great interest are the angle of knife bevel, the amount of knife concave, and the use of a back bevel.

In summary, Mr. Fleischer has made a very good presentation of a type of data that is needed by the veneer and plywood industry. It is to be hoped that this research will be continued.

Mr. Fleischer: Some of the data given in the report may seem somewhat pedantic at present, and to the old-time veneer cutter may even appear to be useless baggage. This problem, of whether his work is being conducted on a practical level and whether it will provide a useful service to the industry, is in fact one that constantly stares the investigator in the face when working in a field of applied science, such as veneer cutting.

It was therefore gratifying to hear, only a short time ago, of one veneer plant cutting softwood veneer on a large scale, where lathe instrumentation has been developed to a high degree, the proper lathe settings for the various species and thicknesses of veneer being obtained by actual measurement instead of "by feel" or by subjective "know-how". This plant started cutting veneer with a green crew somewhat over a year ago. At first much veneer was poorly cut and wasted because of inadequate knowledge of lathe setups. Yet by keeping careful records of those settings that produced the best veneer the crew was able to duplicate these correct settings every time the knife was changed, and as a result the veneer produced is now reported to be uniformly excellent. It is very encouraging to hear of one such plant. No doubt we shall hear of more as time goes on.

Prime Considerations in Molding Plywood*

Thomas R. Miles

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"Molded plywood" is a very versatile process and yields simple, strong, graceful products. Misguided decisions in designing molded products may be avoided by answering a well-established analytical sequence of questions. Can and should it be produced in molded plywood? At reasonable cost? Is it a good product? Compound curvature is to be avoided. Resin choice is important for product quality and production simplicity. The molding method determines both rate of production and quality. Dies are preferred to bag molding. The designer and process engineer should work together from the start.

Introduction

"MOLDED plywood" as a process is very versatile and yields simple, graceful, useful products. Too often, however, the decision to use this method for a particular product is rather hasty and not based on a thoughtful study of the limitations of veneers and resins, the cost of tooling and above all, the final product cost. This paper presents the author's approach in reaching a decision while the item is still in the product design stage.

When we use the term "molded plywood", we are accurately describing a method of producing a laminated or cross-banded, simple- or compound-curved product composed of veneers. Alternate terms such as "bent plywood", "curved plywood", "shaped plywood" infer the possibility of some method of post-forming flat plywood. Henceforth we will use "molded plywood" as meaning the forming of glue-spread veneers to a predetermined shape and permanently bonding under pressure, usually accelerating the process with energy, either heat or radio frequency.

Many enterprising individuals create products, usually furniture items, which may have considerable style, apparent simplicity and sales appeal. Molded plywood has been very popular in this field. Various handcraft publications have contributed fuel to the fire by minimizing the inherent complexity of the process. Having had my share of these products to complete for production (or modification) I have evolved a series of check factors which save many hours of discussion and thought, particularly when convincing the client. The sequence of these factors tends from the general to the specific and experience has shown that after subjecting a product to this treatment the engineering job is essentially complete, as feasibility has been established from both production and cost standpoints.

* Presented by title only.

Reasons for Considering Molded Plywood

Considerations of style, structure, simplification of subsequent production and assembly, and product improvement can logically lead to the use of molded plywood.

Certain styles and structural objectives can only be realized by molding. This is particularly true in modern furniture which uses both factors simultaneously, each predicated on the other. Where structure only is involved as in some industrial and military products, the shape and complexity are inflexibly set, thus resolving it to a materials and manufacturing problem. In many instances a product presently composed of pieces with involved joints may be greatly simplified by molding. Often a convenient degree of restyling will result or can easily be effected. The elimination of intricate joint preparation, gluing and assembly not only reduces cost, but often increases strength and enlarges the choice of species for finishing and customer appeal. Thus, product improvement is also accomplished.

Of course the situation of a customer specifying molded plywood, for reasons of his own, is frequently encountered, again placing the responsibility of processing on the technical ingenuity of the product engineer.

Fundamental Limitations

Compound Curvature

Perhaps the controlling factor in the design of molded plywood products is compound curvature, that is, curvature in two directions

as in the spherical surface of a ball. Compound curvature presupposes a material that will either "draw" or compress fairly readily in any direction without rupture. Metals are alloyed specifically to meet these requirements. Plastics, rubber and other homogeneous materials draw well but are all characterized by a lack of "grain" and are for the most part "man-made" products rather than natural. Nature's vegetable products will submit to single curvature and thus simple draw and compression but will not deform by "flowing" in two directions without failure.

Two alternatives are open to the product engineer: The first and most expedient is to modify the design to simple curvature. In many instances this can be done with almost no apparent change in appearance and with a tremendous increase in the economic feasibility. The second choice is replacement of thick veneers by many thin ones with the further option of laying-up the product on the mold in narrow criss-crossed strips applied individually. This second alternative more than doubles the cost of the product over simple curvature.

Minimum Bending Radius

The other fundamental limitation, minimum bending radius, is actually closely related to compound curvature but also is in itself a determining factor in the design of molded articles. It is sometimes necessary to use a corner radius as small as ½ inch i.d. This seems to always occur with large either flat or very nominally curved adjacent areas. In the latter areas, veneers as thick as ⅛ inch are sometimes employed but the sharp radius demands a maximum of 1/28-inch veneers to mold without failure.

In general, any given thickness of veneer will conform to a smaller radius when the direction of grain is parallel to the axis of the radius rather than when it is perpendicular. Also in general, veneer at 15 percent moisture content will conform to a radius one half that at 5 percent. Further refinements may be made by using a "harness" to wrap the veneer tightly around the mold. Plasticizing the veneers with heat and the moisture in the glue by slowly closing the molds after the veneers contact the heated mold or die surfaces also reduces the allowable radius.

Selection of Materials

Veneer

The maximum allowable veneer thickness has been established by the minimum bending radius, if sharp radii are involved. If nominal radii are involved a layup should be used that places all glue lines as close to the faces as possible, e.g. for ¼-in. 3-ply construction, use 1/14-in. or 1/16-in. face and back and ⅛-in. core. This decreases the pressing cycle with any given die temperature. When facing with rare or exotic veneers, economy usually dictates 1/64-in. faces. In such a case use 5-ply construction with glue applied to defect-free 1/28-in. crossbands. Always balance the construction symmetrically about the core with the same species. In some instances of all-contoured items an even number of plies can be used by paralleling the two center plies as a core.

With most resins an optimum moisture content of about 10 percent should be maintained but with resins setting well below the boiling point of water, veneers of up to 18 percent moisture content may be employed. Such practice is to be avoided if possible, since the rejects caused by "blowing" are more likely and the quality of the resin bond is impaired.

Resin

The choice of the proper resin is one of the most controversial points known to the industry. To avoid detailed entanglement, we shall establish the five general classes for discussion as follows: ureas, modified ureas, melamines, phenolics, and resorcinols.

The order named is approximately the progression of their relative moisture and exposure resistance and incidentally price, ureas having the least resistance, and lowest cost, resorcinols the most resistance and the highest cost.

If the molded article is to be used under exposed conditions, start with melamines. If interior use is anticipated ureas or modified ureas are adequate. Each resin has its own particular advantages and disadvantages from a production viewpoint and these, together with the variations commercially available, leave considerable latitude in choice.

After consideration of exposure resistance comes the resin's reaction to the type of accelerating energy employed. They all react favorably to conducted heat, properly applied. Radio

frequency is more selective, working well on ureas, melamines and resorcinols but arcing badly on phenolics.

Craze resistance and gap-filling characteristics are a factor with low pressures used in bag molding, the modified ureas filling this requirement most satisfactorily.

Bleeding-through thin face veneers is a troublesome problem that must be considered. Ureas with proper extending fillers, melamines with drying of the spread resin prior to layup and pressing are possible solutions.

Cold pressing of relatively simple shapes, such as chair backs, is commonly done with vegetable glues, ureas or even resorcinols. The moisture content is of slightly less importance in cold pressing.

The final choice of resin or glue is heavily influenced by the method of molding employed and the resulting pressing cycle.

Selection of the Molding Method

Most products that can be die molded can also be bag molded but the reverse is less often true, the shape and size dictating the method. Large, bulky shapes with perhaps some compound curvature are best bag molded, but fortunately the quantity required is usually nominal. The relative product value is high.

Smaller, simpler shapes should always be die molded if possible. The dies may cost more per square foot of product but decrease of pressing cycle, fewer rejects, and almost no maintenance or repair will demonstrate their superior choice. Further, it is probable that a multiple-opening family of dies may be used in a single press frame where only a single bag opening would be possible.

The total quantity to be manufactured is often the deciding factor. Quantities of 10,000 and up should be die molded if possible.

The use of conducted heat from the dies usually achieves a shorter pressing cycle than conduction from a mold on one side and electric blanket on the bag side. When radio frequency is to be employed, the bag, with incorporated electrode on the fluid pressure side and a wooden die faced with the other electrode, is common practice. Often both dies can be made of wood and faced with a rubber slab under one or both electrodes, thus a semblance of fluid pressure is achieved, depending on the hardness of the rubber and the pressure. Another possibility is the use of "conductive rubber" resistance sheets with wooden dies.

For the inevitable experimental or "sample" parts the latter heating method is to be recommended, either using two wooden dies or a wooden mold and bag.

The principle advantage of radio frequency is the very short pressing cycle, permitting a larger quantity of piece production on the same tools per day. Comparing r.f. with conducted heat, a ratio of 2:1 is common, sometimes reaching 6:1 with the loading-unloading cycle as a limit. Cost of equipment is considerably increased with r.f. unless it is already standard in the plant.

Either electrical energy or steam is such a very small percentage of the total production cost that the choice is decided on availability.

Careful consideration should be given to the pressure necessary to produce a strong permanent bond. Dies will allow the use of almost any desired pressure, 200 psi and up, while 100 psi is high for bag molding and borderline for product quality.

Die molded products meet a higher quality standard and are superior in smoothness of surface on both sides. Bag molded surfaces accumulate any inconsistencies in veneer thickness on the bag or fluid pressure side, necessitating excessive sanding prior to finishing.

If however, the tools can be designed to leave the mold side for finishing and the anticipated production is nominal, e.g. 5000 units total, the resulting cycle not excessive, the bag molding method will suffice.

Bag molding has a distinct advantage in parts involving compound curvature by applying the pressure in a "flowing" manner rather than coming down abruptly. If this effect can be made to work *for* you it is sometimes the sought-after answer.

Finally, the total quantity on order and anticipated delivery schedules, plus the expediency of tool making often are the deciding factors in choosing the molding method.

Design of Tools

Since we have decided on the most practical method of molding the product we now have to decide the type of tools.

The general method of producing one experimental tool-up for samples has just been described. In some instances the use of a hard plaster such as "Hydrocal" extended with fibrous sisal or asbestos will expediently produce temporary dies or molds good for a dozen or so samples. Conductive rubber is the best heat source.

For permanent tooling in the quantity production of a quality article, metal dies are indicated. These may be cast or fabricated by welding formed plate. Fabrication has one outstanding inherent advantage; if dies can be rolled from ½-in. steel plate, without "bumping", they have simple curvature and therefore will easily make good molded plywood. Such fabricated dies are easily heated by welding tight all joints and using steam directly in the back of the die. Thus a very uniform temperature distribution is obtained and the steam pressure controls the temperature range. If plant steam is not available, small electric boilers are obtainable at nominal cost and provide a readily controllable method of using electrical energy. The small amount of metal to be removed or added in mating is easily accomplished by regular grinding when high, or metal spraying when low. A word of caution: Fabricated dies should be designed and built by experienced designers and welders.

Cast dies are of two types, one containing imbedded steam coils or electric cartridge heaters, the other a plain casting, usually thinner, bolted in contact with a heated flat platen. When molding a variety of nominal curves the latter is more economical and is easily changed for short return orders. Aluminum and Kirksite-type metals are both used in casting dies. For most items aluminum is the logical choice because its light weight permits easy handling and it is one of the best conductors of heat. Although the price per pound is much higher than the Kirksite-type metals, aluminum weighs approximately one-third as much, the comparative finished costs being about the same.

A recent example illustrates some of the advantages of fabrication over casting: A chair was designed with the seat and back in one piece. The experimental plaster dies made sufficient samples for customer acceptance and an order was placed for delivery "yesterday". It was found that castings would require at least 8 weeks and cost approximately $4,000.00. A rough check showed that fabrication would at least beat that time so the decision was made to fabricate, using ½-in. plate. Four weeks from the start of the detail designing the dies were delivered and cost $1,500.00. A trial impression revealed a maximum of 1/16-in. out of parallel in the mating surfaces. After removing the die set only twice for build-up and grinding they checked out satisfactorily and went into production, the "proofing" time—2 days.

When tooling for r.f., wooden dies of vertically laminated plywood, bandsawed and sanded, are quite satisfactory. It is well to place a smooth sheet of ⅛-in. plywood over the wood or use a heavier metal electrode against the wood.

In constructing the bags for bag molding, a form should be built slightly smaller (1/16-in.) than the shape to be made and the bag built up of nylon-reinforced rubber sheets cemented together with uncured rubber. The bag is then cured under infra-red lamps with a vacuum applied between the form and the bag. Care in construction of the bags will reduce the incidence of "down time" on the production line and prolong the number of cycles. Sometimes a bag will go 15 cycles and at other times 5000, depending on its workmanship, design, pressure and heat.

Another factor influencing the decisions in tooling is the availability of skilled mechanics and well equipped shops in the local area.

Production and Cost Evaluation

With the decisions made up to this point we are able to sum up the total cost by the following general break down:

1. Engineering—design and planning
2. Tooling—dies, jigs and fixtures
3. Materials—going into product
   a. Veneer—including fall-down
   b. Resin—including waste
   c. Finishes
   d. Miscellaneous
4. Pro-rated charge-off of special equipment required to produce the product as planned

We now take a serious look at the size of the order and the anticipated repeats. Assuming that full-scale production is warranted, or demanded by the customer, we make an operation sheet and using current productivity and good planning sense establish the optimum rate of production. This leads directly to a reliable cost estimate by applying wages. If the rate of production is satisfactory to meet demands it is an unusual situation, if not, then find the primary bottlenecks and concentrate all ingenuity there, *while it's still on paper*. Perhaps a different resin will make up the shortage, or doubling the tooling as a last resort. In any case the limits of variation have been already methodically covered and there are only two simultaneous equations to solve, not six. If the optimum rate is greater than desired and quality is given as much credit as it deserves, avoid cutting down on the type of tooling. The number of dies etc. may be reduced but avoid compromising the method. With the newly established operation sheet to meet production, the following additional costs may be added to the previous four:

5. Direct labor
6. Overhead
7. Packaging and shipping

Thus a complete cost is determined with exact knowledge as to distribution and undoubtedly an awareness of items that will bear further study for reduction or must be carefully watched for increase.

By adding the usual percentage of profit, including a contingency to "handicap" the estimate in the light of previous proven examples, a price and delivery schedule may be quoted.

The execution of this series of considerations is always accompanied by many sketches, tabulations and incidental ideas. These should be organized at once into a brief but coherent series of notes for future reference, when the actual design and production is authorized. It pays.

Conclusions

The basic reason for using molded plywood should be determined for each product.

Compound curvature is to be avoided if at all possible.

The proper resin for the product end-use is mandatory.

The type and quality of the tooling is very important, fabricated dies being preferred to cast dies, and either to bag molding.

A choice of molded plywood should depend on the answers to the four following questions:

Can it be produced in molded plywood?
Should it be produced in molded plywood?
Is the cost reasonable and competitive?
Is it a good product?

A conclusion as to whether molded plywood is the proper process can now be reliably drawn in a relatively short time while the product is still in the design stage.

The use of molded plywood enlarges the scope of the designer in wood and when combining his efforts with the skill and ingenuity of a process engineer the result is both practical and beautiful.

FOREST PRODUCTS RESEARCH SOCIETY

Energy Requirements For Insert-Point Circular Headsaws*

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Forces used in sawing with an insert-point circular headsaw were measured. Attempts were made to evaluate the effects of changing saw characteristics, such as hook angle, tooth width, and running speeds; and changing sample characteristics, such as cutting depth and wood density. Tables were derived of horsepower required for saw speeds, feed rates, cutting depths, and wood densities to be expected in mill operations. The relation between gullet size and wood to be chambered was explored.

PUBLISHED material on the fundamental aspects of rip-sawing with circular saws is meager. It is mainly included in the references *(1)* to *(6)* listed at the end of this report. None of these deal with insert-point saws, operated in conformance with American practice on American species; much is theoretical rather than based upon actual tests, and coverage of some essentials is lacking.

The paper here presented gives the results of work at the Forest Products Laboratory in determining the effect of sawtooth form and operating speeds of saw and carriage on the consumption of power in ripping logs under conditions normally encountered in circular head-rig sawmills. It was a full-scale study in that standard-sized saws and typical small-mill equipment were employed for practical cutting depths at the normal range of feed and saw speeds.

The following specific points were studied in order to determine how power consumption varies with: (1) feed rate, (2) width of sawed face, (3) wood density, (4) kerf width, (5) hook angle, (6) temperature (frozen compared with unfrozen), (7) feed against tooth travel (normal) and with tooth travel (climb cutting), (8) knotty compared with clear areas, (9) saw diameter, (10) number and style of teeth, (11) dull compared with sharp saws, and (12) what gullet space is required per unit of wood removed. The immediate objectives were, first, a tabulation of horsepower requirements for circular headsaws operating within the range normally encountered, and second, the limits of cutting rate imposed by gullets; namely, the optimum ratio between gullet space required and wood removed.

Test Equipment Used

The sawmill upon which the tests were made was a standard type of medium size and weighed approximately 4,000 pounds (Fig. 1). Instead of the usual belt or friction feed connected to the saw mandrel, an independent system was used consisting of a 15-hp. electric motor belted to a variable transmission drive

Fig. 1.—Standard-sized saws and typical sawmill equipment used at Forest Products Laboratory in conducting power consumption tests.

* Presented by title only.

[1] Acknowledgment is made to L. H. Reineke and F. B. Malcolm of the Forest Products Laboratory for assistance in conducting the study here reported.

[2] Maintained at Madison 5, Wis., in cooperation with the University of Wisconsin.

and through reduction drives to the drum. Gears and clutches in the drum interior were actuated by hydraulic cylinders as in the rear axle of a truck brake. The control of these clutches was brought to the sawyer's levers by connecting the lever to two hydraulic cylinders anchored to the husk and connecting these in turn to the drum cylinders by hydraulic oil lines. This combination permitted positive feeds at any desired rate between 30 and 300 feet per minute.

The saw was powered by a 75 hp. electric motor at 1,800 r.p.m. A flexible coupling connected the motor shaft to a gear reducer capable of three different output speeds. A torque meter was placed as a continuation of the output shaft and power was delivered to the saw through pulleys and belts. This combination permitted saw speeds of 300, 450, and 600 r.p.m.

The force used in operating the saw was measured by a torque meter of 5,000 pound-inches capacity. The force used in pulling the carriage was measured with a strain gage attached to the anchor bolt of the sheave carrying the cable pulling the carriage. These instruments were connected to a 5-inch oscilloscope located in an instrument house (Fig. 2). Additional recording equipment was an electric tachometer belted to the saw mandrel and a slide-wire potentiometer connected to the carriage, each connected to a second oscilloscope. Records of events portrayed on both oscilloscope screens were permanently recorded by camera.

Saws having a diameter of 48 inches with B style[3] teeth were used in all tests with the following additions: In the test of gullet capacity a 48-inch diameter saw with forty eight 2½ style teeth was also used; in the saw diameter test a 60-inch diameter saw with 46 B style teeth was also used; in the tooth style and number test a 48-inch diameter saw with forty eight 2½ style teeth, a 48-inch diameter saw with fifty four 2½ style teeth, and a 48-inch diameter saw with 40 No. 3 style teeth were also used. All were 7–8 gage and teeth were sharpened with a power emery wheel to insure uniformity.

[3] For description of style of teeth see saw manufacturers' catalogues.

Material Used

For testing saw factors the wood used was especially selected for maximum uniformity in size, texture, and physical properties. Practically clear Douglas fir cants, 10 inches thick with not fewer than six rings per inch, were used. This material was kept under conditions assuring little change in moisture contents. For testing wood factors, cants cut from a number of different species were used.

General Method

The test saw cuts were made across the ring direction (edge grain sawing). Moisture contents and specific gravity (oven-dry weight based on green volume) were taken for each cut. Because temperature effects might prove a factor, the temperatures of some of the cants were recorded but such measurements were discontinued when analysis indicated no correlation between temperature and power consumption except in the test of frozen contrasted with unfrozen material.

Method and Findings of Individual Tests

Test 1. Force Related to Feed Rate

In the test to determine the relationship between force and bite[4] per tooth a saw 48 inches in diameter with 40 B style teeth, 9/32 inch wide, and with a hook angle of 43° was used at saw speeds of 300, 450, and 600 r.p.m.; and feed rates approximately 1/32, 1/24, 1/16, and ⅛ inch per tooth in Douglas fir cants 10 inches thick and 14 feet long. A single cut was taken in each of five cants at the four feed rates and at the three different saw speeds, totaling 60 cuts. However, the series of five cuts for a bite of ⅛ inch at 600 r.p.m. were discarded, since the saw failed to cut a true line at this high production rate.

[4] Carriage speed, correlated with saw r.p.m. and number of teeth, determined the feed rate per tooth. In the following discussions the phrase "bite per tooth" is used to indicate feed rate. This "bite per tooth" was measured for each cut by taking the total interval included in from 6 to 10 consecutive saw revolutions and computing the "bite".

Example: The saw had 40 teeth, the total interval for 10 revolutions was 26 inches and for one revolution 2.6 inches, hence the "bite" is $\frac{2.60}{40} = 0.065$ inch.

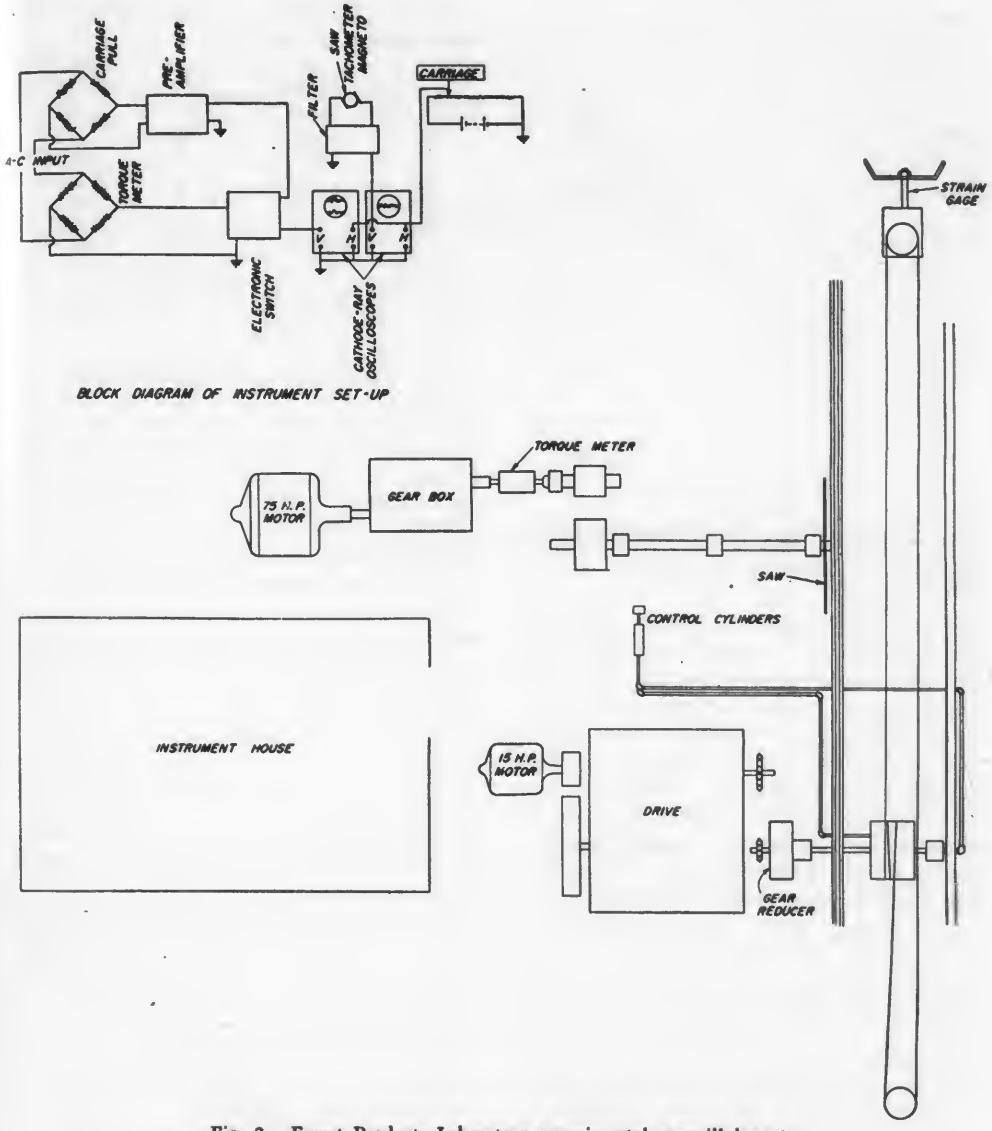

Fig. 2.—Forest Products Laboratory experimental sawmill layout.

A subsequent test indicated that density is an important factor in power consumption, hence the force values for the individual cuts were adjusted for an average density. Cutting torque, which is the torque employed solely to force the saw through the cut and excludes torque registered when the saw is not cutting, was read from the oscilloscope photographs for each saw line. The average torque for each of the 5-cant series was adjusted to the average specific gravity of 0.4266 and plotted against bite (Fig. 3).

Figure 3 indicates that cutting torque varies directly with the bite (except at low bites) and, for similar bites, inversely with the saw speed. One practical application of these relationships is in recommending saw speeds where power conservation is essential. For a given

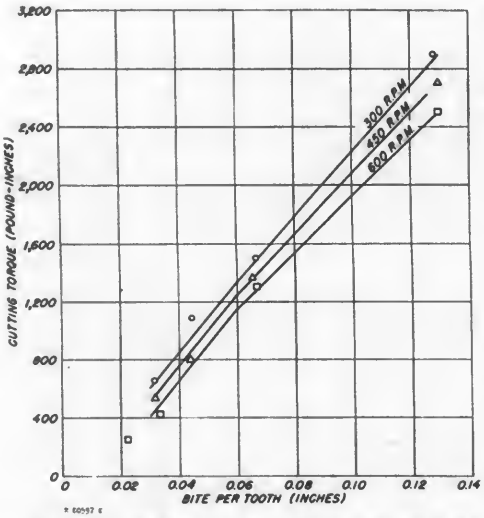

Fig. 3.—Cutting torque for different bites and saw speeds at cutting depth of 10 inches and average specific gravity of 0.4266.

rate of carriage feed this cutting torque was disproportionately increased by reducing the saw r.p.m. For example, from Fig. 3 the cutting torque for a bite of 0.06 inch at 600 r.p.m. is 1,150 pound-inches; for a bite of 0.12 inch at 300 r.p.m. it is 2,675 pound-inches. For the 40-tooth saw this is a carriage feed of 120 feet per minute in each case. Thus for similar footage production the cutting torque at 600 r.p.m. was less than half that at 300 r.p.m. Converted to horsepower this relationship is 21.9 horsepower at 600 r.p.m. and 24.9 horsepower at 300 r.p.m. For field application the additional horsepower required to turn the shafts and pull the carriage must be added (Table 1). Under the conditions of test this

TABLE 1.—TOTAL HORSEPOWER (CUTTING, TRANSMISSION, CARRIAGE PULL) FOR DIFFERENT BITES AND SAW SPEEDS

Bite	300 r.p.m.	450 r.p.m.	600 r.p.m.
Inch	Horsepower	Horsepower	Horsepower
0.13	12.2	16.9	20.6
.04	14.5	20.2	25.1
.06	19.1	27.3	34.0
.08	23.4	33.3	42.0
.10	27.7	39.2	49.4
.12	31.9	45.2	56.8
.13	34.1	48.1	60.4

noncutting horsepower requirement more than balanced the gain had by speeding up the saw, resulting in a slight overall economy in horsepower consumption through slowing down the saw. The following direct comparisons are from Table 1.

Carriage feed	Saw speed	Bite per tooth	Total power consumption
Ft. per min.	R.p.m.	Inch	Hp.
60	600	0.03	20.6
60	300	.06	19.1
80	600	.04	25.1
80	300	.08	23.4
120	600	.06	34.0
120	300	.12	31.9

Presumably at most sawmills the more efficient use of horsepower results from lower as contrasted with higher saw speeds.

Test 2. Force Related to Depth of Cut

This test was run by sawing at 300 r.p.m. cants tapering from 10 inches thick at the front end to 19 inches thick at the back, at a bite approximating 0.065 inch and including 10 different species. Five cuts taken in each species and resulting torque values averaged by species and plotted torque over depth of cut for a given density gave the record of torque at cutting depths from 10 to 18 inches at this bite and saw speed for the various wood densities used as shown in Fig. 4.

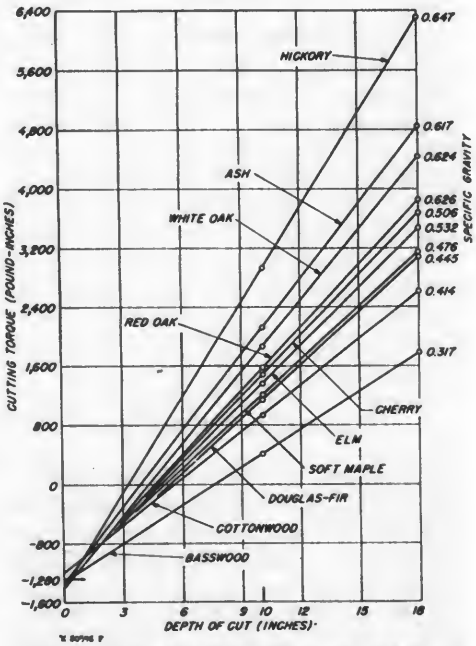

Fig. 4.—Cutting torque for cutting depths 10 to 18 inches for stated specific gravities at 300 r.p.m saw speed and 0.0645 inch bite.

The effect of cutting depth was indicated as a straight line relationship for this range of depths with a common origin at a cutting torque of –1,280 pound-inches; the cutting torque for 12-, 14-, 16-, and 18-inch depths was 1.2, 1.4, 1.6, and 1.8 times that for the 10-inch depth.

In a second series of tests to determine if cutting at the top of the saw as contrasted with cutting in front of the mandrel showed differences, three cuts were taken in each of three Douglas fir cants 10 inches thick. The front end of the cant rested on the front bolster and the rear end was blocked up so that the top of the saw coincided with the top of the cant as the front of the saw emerged at the end of the cut. No consistent difference was noted in force expenditure when sawing in these different zones of the saw rim.

Test 3. Force Related to Specific Gravity

Five cuts for each of ten species were taken in cants tapering from 10 inches at the front to 19 inches at the back end at a bite approximating 0.065 inch. The species and average specific gravity for each are shown in Fig. 5. The maximum cutting depth was 17⅝ inches, somewhat less than the 19 inches maximum cant depth, because the front of the saw was out of the cant before the top of the saw (2 feet behind) reached the high point of the cant. This maximum depth of 17⅝ inches was not sufficient to overload the saw to a stalling condition at the feed rate used (0.065 inch) with basswood, cottonwood, Douglas fir, soft maple, cherry, and elm. Stalling occurred in four of the five cuts in red oak, and in the other cut the saw barely avoided stalling. Stalling occurred in all cuts of white ash, white oak, and hickory. Stalling permitted determination of maximum gullet capacity and the cutting depth at which overloading began without interfering with the analysis of torque with respect to cutting depth.

The depth of cut at the start and finish of the unstalled portion of the cut was taken and the average torque for each species at cutting depths from 10 to 18 inches plotted in Fig. 5 against specific gravity for each cutting depth of 10, 12, 14, 16, and 18 inches. The resulting lines tended to converge at the origin of –1,280 cutting torque, to which they were adjusted

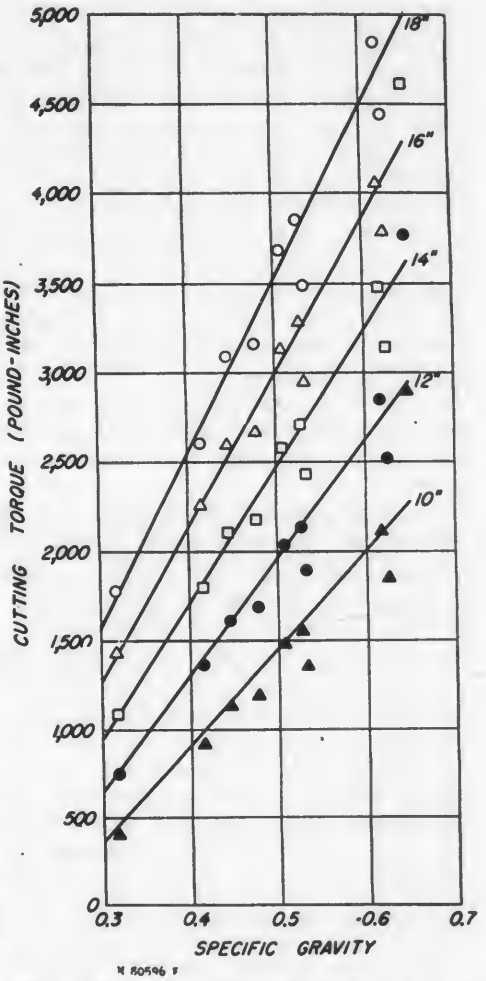

Fig. 5.—Torque for cutting depths 10 to 18 inches at 300 r.p.m. saw speed and 0.0645-inch bite.

(Fig. 5). Since negative torque is untenable, values for depths of cut less than 10 inches are not justified. Torque varied directly with specific gravity. The close correlation between cutting torque and specific gravity justifies basing horsepower requirement tables on these data amplified for other bites and saw species by drawing on test 1, "Torque related to bite and saw speed."

Test 4. Force Related to Width of Kerf

Insert teeth labeled 10/32, 9/32, 8/32, and 7/32 inch were used in the condition as received from the factory. Inability to cut a

straight line with the 7/32-inch teeth resulted in eliminating this size. Five cuts were taken with each of the others in a Douglas fir cant 10 inches thick at a feed of 0.0684 inch per tooth. The resulting torques were 1,600 pound-inches for the 10/32-inch, 1,460 for the 9/32-inch, and 1,028 for the 8/32-inch teeth. Thus the expected direct variation of torque with tooth width was indicated. The 7/32-inch width was inadequate, the 8/32-inch width proved most economical of power. Tests were not protracted to determine if rim heat might result in a continuous run with the 8/32-inch tooth. The thickest part of the holder is 0.205 inch. The 7/32-inch tooth was thus freed by 0.014 inch (0.219–0.205); and the 8/32-inch tooth had a clearance of 0.045 inch (0.250–0.205).

A check on torque recordings for cutting depths from 0 to 10 inches indicated that (1) below a cutting depth of approximately 2 inches no torque was recorded, and (2) in progressing from 2 to 10 inches cutting depth the rate of torque increase was in close agreement with that for depths of 10 to 18 inches for comparable specific gravities and feeds. Obviously the instruments used in these tests were not sensitive to very light loads; hence, values in the tables 3, 4, and 5 are presumably too low for the slowest carriage feeds, when cutting the minimum depths in the lowest specific gravity class.

Test 5. Force Related to Hook Angle

Five cuts were made in a Douglas fir cant 10 inches thick for each of a series of hook angles of 41°, 28°, and 15° at an average feed of 0.064 inch per tooth. The resulting torque values were adjusted to those at the average specific gravity for the group (0.4967) and each 5-cut series averaged. The results were as follows:

(a) Approximately the same initial torque resulted for the 15° and 41° hook angles, and approximately 10 percent less for the 28° angle.

(b) For the 41° hook angle a decrease of torque at the midzone and a pick-up to starting levels at the end zone.

(c) For the 28° hook angle the torque held constant throughout.

(d) For the 15° hook angle the torque increased from the initial entry, being approximately 33 percent more at the end than at the beginning.

The saw functioned well at hook angles of 41° and 28°, but at 15° it failed to cut a true line, the saw being dished or distorted from a plane. It is assumed that the increase in torque as cutting progressed was largely due to friction as the side of the saw pressed against the cant.

Test 6. Force Used in Cutting Frozen Compared With Unfrozen Material

Ten-inch cants of Douglas fir, cottonwood, and basswood in both a frozen (–6° F.) and unfrozen (70° F.) condition, sawn with a feed of 0.06 inch per tooth, resulted in the following torque values:

Species	Torque	
	Frozen Pound–inches	Unfrozen Pound–inches
Douglas fir	1,350	1,526
Cottonwood	758	758
Basswood	444	599

The slight trend of increased torque for unfrozen as compared with frozen material was contrary to trend in tests made for such physical properties as bending or shear. If these torque values are valid, the implication is that the very real difficulty in sawing some species when frozen is due to other than pure force requirements.

Test 7. Force Used in Cutting Under Compared With Over the Mandrel

A Douglas fir cant 10 inches thick was placed with the front end on the front bolsters and the rear and elevated 9 inches. Four cuts at a feed of 0.06 inch per tooth were taken with the saw running in the normal direction. The electric motor was then run in a reverse direction with the saw turned around, and four cuts taken in the same cant, feeding in the same direction as before. It was assumed that this second set-up with the teeth entering the cant at the bottom simulated conditions of "climb sawing" in which the tooth travel during cutting is in the same direction as the feed, rather than opposed to it as in normal sawing. The torque for "climb" sawing was approximately 2.7 times that for normal. This is contrary to findings in metal sawing where "climb"

sawing shows a more efficient use of power than does normal sawing.

Test 8. Force Related to Knots

Four cuts were made in a Douglas fir cant 10 inches thick at a feed rate approximating 0.06 inch per tooth. The cant was boxheart; the cuts traversed both spike and round knots. The torque for cutting areas free from knots approximated that for similar tests in Douglas fir clears. Knots did not occupy the area of the full cutting arc in any instance; hence values for cutting 100 percent knotty areas were lacking. Where teeth passed through an area in which knots occupied 40 percent of the cutting arc the torque was 70 percent greater than for wholly clear areas. From this it might be deduced that the force required for Douglas fir knots was approximately three times that for clear areas.

Test 9. Force Related to Saw Diameter

This test dealt with the force used in sawing with a 48-inch diameter, 40-tooth saw compared with that in sawing with a 60-inch diameter, 46-tooth saw, each of 7–8 gage, B style tooth 9/32 inch wide and a hook angle of 43°. Feed rates per tooth approximated 1/32, 1/24, 1/16, and 1/8 inch per tooth. Two cuts at each bite for each saw were taken from cants 7 inches thick and first placed directly on the bolsters, then elevated 7 inches. Similar cuts were taken on cants 5 inches thick with the cant elevated 14 inches above the bolsters. The aggregate cutting depth for the three positions of 19 inches equaled the total cutting depth possible with the 48-inch diameter saw and was 6 inches less than that for the 60-inch diameter saw. The general relationship was that the 60-inch diameter saw required between 24 and 36 percent more torque to saw the cumulative 19-inch depth. Since torque is the product of the radius and the force and since the 60-inch diameter saw is 25 percent greater than the 48-inch diameter saw, this test indicates that the force was little if any different.

Test 10. Comparison of Cutting Force for Saws With Differing Tooth Styles or Differing Number of Teeth

Four saws, each of 48-inch diameter, 7–8 gage, fitted with teeth of like width, were used to take five cuts per saw in a Douglas fir cant 10 inches thick at a feed rate of 2.73 inches per revolution of the saw. A tabulation of essential saw characteristics and resulting torques follows:

Saw No.	Style of tooth	Teeth	Torque
		Number	Pound-inches
1	2½	54	1,104
2	2½	48	1,032
3	B	40	787
4	No. 3	40	748

The torque values for saws 1 and 2 and again for 3 and 4 are not greatly dissimilar within the pairs and the dissimilarity could well be attributed to slight differences in aligning the teeth and holders to the plane of the saw. Tooth styles B and No. 3 differ but little and the torque values differ but little. Style 2½ differs greatly from styles B and No. 3 in the arc of curvature of the gullet and in its reduced gullet area, and the torque values differ greatly. From these comparisons it might be deduced that style of tooth influences the force requirements. The warranted deduction is that the number of teeth rather than the style is the dominant factor and that torque could be expected to vary directly with the number of teeth.

Test 11. Comparison of Cutting With Dull and Sharp Teeth and Comparison in Cutting With Holders or Teeth Out of and in Line With the Saw Plane

Five cuts were taken in a Douglas fir cant 10 inches thick using teeth dulled by cutting several thousand board feet of oak. The teeth were sharpened and a matched series of five cuts taken, the feed rate in both series approximating 2.86 inches per saw revolution. The before-sharpening torque averaged 1,301 and the after-sharpening torque averaged 1,205 pound-inches, which is an 8 percent increase in force required for the dull over the sharp teeth.

A distinct scoring of the sawed surface resulted when teeth or holders were visibly out of line with the saw plane. Upon re-aligning the teeth or holders and eliminating this pronounced scoring approximately 12 percent less torque was required.

Comparable scorings resulted from a flutter in the rim of the saw which was traceable to inaccurate facing of the saw collar. This was corrected by grinding. Approximately 10 per-

cent more torque was used to cut a 10 inch depth before grinding than after grinding. The results of these three series of observations indicate that emphasis should be given to insuring that the saw be able to cut a smooth face as well as maintaining sharp teeth.

Test 12: Gullet Space Required Per Unit of Wood Removed

Two different gullet patterns were tested, the 2½ style having a profile area of 1.5 square inches and the B style with 2.5 square inches. The profile area was taken as the area in square inches found in planimetering the outline of the tooth and gullet. Saws differed only in the number of teeth, that is, 48 for the 2½ style and 40 for the B style. Tests for the 2½ style tooth were made on Douglas fir cants and for the B style tooth on ash, red oak, and white oak. Tapered cants were used at a feed rate adequate to overload the gullets as cutting depth increased. The taper provided an automatic increase in cutting depth with a corresponding increase in cutting torque. In some cuts, however, a depth was reached at which the torque increased at an accelerated rate (Fig. 6). This was interpreted as due to overloading the gullet. The depth of the cut where the

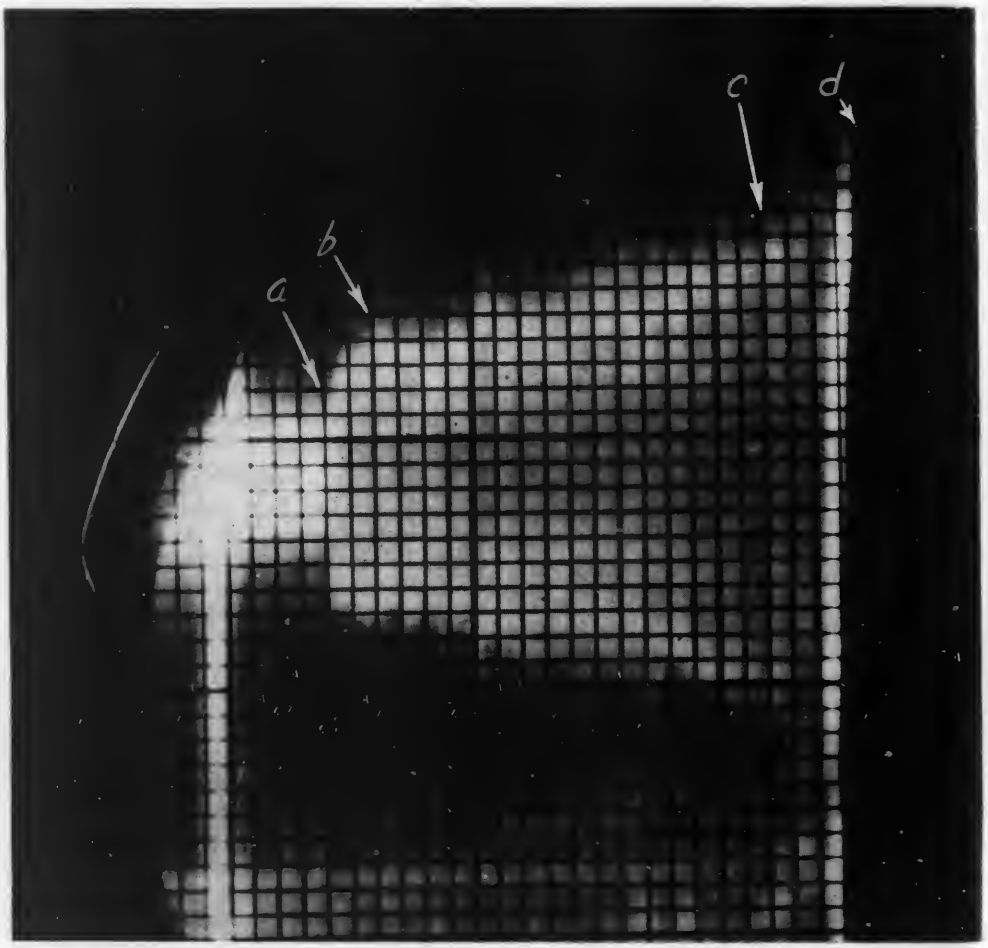

Fig. 6.—Oscillogram of torque acceleration due to exceeding capacity of gullets. (a) Amplitude for saw idling; (b) initial amplitude in cut; (c) amplitude at point where gullets overloaded; (d) stall amplitude.

acceleration began plus the bite per tooth provided the basis for computing gullet space requirement to wood removed ratios. Prior to actual stalling the bite held uniformly to within two or three final tooth cuts, but usually in the final 2 inches of peripheral travel the saw speed dropped very rapidly, whereas the feed held up so that the tooth chiselled ahead, taking a bite as much as ¾ inch in softwoods and ½ inch in hardwoods. Fig. 7 shows the clogged gullets at stalling.

The tests indicated that the ratio of gullet space required (profile area) to wood removed was for the 2½ style tooth in Douglas fir 2.38 to 1, and for the B style tooth in ash and oak 2.5 to 1. The following species did not show a torque acceleration when cut at the listed ratios—cherry 2.26, basswood 2.22, elm and cottonwood 2.18, soft maple 2.14 to 1. Therefore, the ratios for these species must be less than those listed.

Horsepower Requirements for Saw r.p.m. 300, 450, 600 at Feeds 0.03 to 0.13 Inch per Tooth, for Specific Gravities 0.3 to 0.65 Through Depths 10 to 18 Inches

Tables of horsepower requirements were developed from data obtained in tests 1 and 3. The required tables were made by using the values of cutting torque for the series of cutting depths and specific gravities investigated and extending these from the single bite and saw speed used to the series of bites and saw speeds used in test 1. For such extensions conversion ratios based on test 1 data were applied to actual values of test 3. For example, values of cutting torque were converted from those for a bite of 0.0645 inch to those for 0.06 inch by a ratio derived from Fig. 3 as follows: Value for a bite of 0.06 inch at 300 r.p.m. = 1,335 and for a bite of 0.13 inch = 2,900. In 7 units of bite the torque difference is 1,565; hence, the percentage change $= \frac{1,565}{1,335}$ or

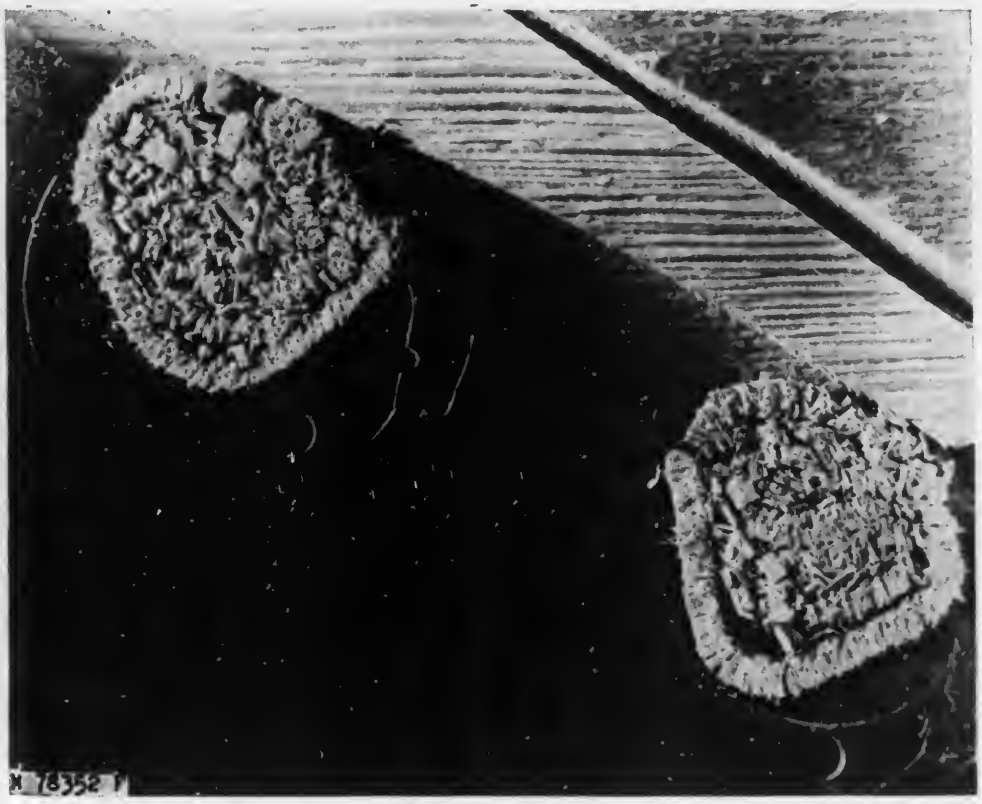

Fig. 7.—Photograph of clogged gullets at stalling.

117.2 percent and for each unit of 0.01 inch bite the change is 16.7 percent. For 0.0045 inch (0.0645 to 0.06 inch) subtract 0.45 × 16.7 percent or 7.5 percent from the values on Fig. 5 for the 10-inch cutting depth. The assumption is that this ratio change as found for a specific gravity of 0.4266 can be directly applied to all other specific gravities listed.

Values for bites of 0.08, 0.10, 0.12, and 0.13 inch were computed by adding 16.7 percent per 0.01-inch bite increase to the values. For bites of 0.04 and 0.03 inch the ratio changes. (Below bites of 0.06 inch a curved, not a straight line, relationship holds for torque on bite as indicated in Fig. 3.)

These torques were converted to horsepower as follows:

$$\text{Horsepower} = \frac{\text{torque} \times \text{r.p.m.} \times 6.2832}{33{,}000 \times 12}$$

The r.p.m. of the torque meter for 300 r.p.m. saw is 600. Therefore, horsepower = torque × 0.00952.

The resulting horsepower are tabulated in Table 2.

TABLE 2.—CUTTING HORSEPOWER EXCLUSIVE OF MACHINE LOSS HORSEPOWER FOR SPECIFIED BITES

Saw r.p.m. = 300

Bite Inch	Specific gravity	Cutting depth 10 inches Horsepower
0.03	0.3	1.4
.04	.3	2.0
.06	.3	3.1
.08	.3	4.1
.10	.3	5.1
.12	.3	6.1
.13	.3	6.6
.03	.4	3.6
.04	.4	5.1
.06	.4	8.0
.08	.4	10.5
.10	.4	13.0
.12	.4	15.5
.13	.4	16.8
.03	.5	5.8
.04	.5	8.1
.06	.5	12.8
.08	.5	16.9
.10	.5	20.9
.12	.5	25.0
.13	.5	27.1
.03	.6	8.0
.04	.6	11.2
.06	.6	17.6
.08	.6	23.2
.10	.6	28.8
.12	.6	34.4
.13	.6	37.3
.03	.65	9.1
.04	.65	12.8
.06	.65	20.0
.08	.65	26.4
.10	.65	32.8
.12	.65	39.2
.13	.65	42.4

To get the horsepower for other depths (Table 3) first a constant of 12.2 horsepower was added to the values of Table 2 (—1,280 pound-inches torque at 300 r.p.m. = 12.2 horsepower) and the result multiplied by 1.2, 1.4, 1.6, and 1.8, then the 12.2 horsepower subtracted to get horsepower at cutting depths of 12, 14, 16, and 18 inches, respectively. In a similar manner horsepower tables were computed for saw speeds of 600 r.p.m. (Table 4) and 450 r.p.m. (Table 5).

Summary and Conclusions

The characteristics of the four dominant factors influencing power consumption in sawing (feed rate, depth of cut, density, and saw speed) may be summarized as follows.

The cutting torque was directly proportional to the feed rate for feeds above 0.06-inch per tooth. For feeds between 0.06 and 0.03-inch per tooth, a unit rate of feed decrease showed a greater than proportional rate of torque decrease. This held true in cutting 10-inch depths in wood of 0.426 specific gravity and was indirectly corroborated by other tests of the series. If, however, the torque required to run the transmission and saw plus carriage drive (usually powered from the mandrel) be added, a slight increase in efficiency of power use resulted from decreasing the saw speed.

The overall effect of depth of cut was a straight-line relationship—the cutting torque for 12-, 14-, 16-, and 18-inch depths was 1.2, 1.4, 1.6, and 1.8 times that for the 10-inch depth when the 1,280 pound-inches below origin was added.

The effect of specific gravity was a direct variation in cutting torque with specific gravity.

The effects of feed rate, cutting depth, density, and saw speed are embodied in the tables on horsepower requirements.

A tooth width 0.045 inch greater than the thickest part of the holder resulted in the least torque expenditure. With no clearance, accurate sawing was impossible; with greater clearance torque requirements increased. Insufficient tests were made to determine if saw heating would result from prolonged action with 0.045-inch clearance.

Hook angle had but slight influence within the range of 41° to 28°, but at 15° the saw

TABLE 3.—CUTTING HORSEPOWER EXCLUSIVE OF MACHINE LOSS HORSEPOWER[1]
(r.p.m. of saw = 300, r.p.m. of torque meter = 600)

$$\text{Hp.} = \frac{\text{Torque} \times \text{r.p.m.} \times 6.2832}{33{,}000 \times 12} = \text{Torque} \times 0.00952$$

Bite per tooth	Carriage feed for a 40-tooth saw	Specific gravity[2]	Depth of cut—Inches				
			10	12	14	16	18
Inch	Ft. per min.		Hp.	Hp.	Hp.	Hp.	Hp.
0.03	30	0.3	1.4	4.1	6.8	9.5	12.8
.04	40	.3	2.0	4.8	7.7	10.5	13.4
.06	60	.3	3.1	6.1	9.2	12.2	15.3
.08	80	.3	4.1	7.3	10.5	13.8	17.0
.10	100	.3	5.1	8.5	11.9	15.3	18.7
.12	120	.3	6.1	9.7	13.3	16.9	20.4
.13	130	.3	6.6	10.2	13.9	17.5	21.2
.03	30	.4	3.6	6.7	9.9	13.0	16.2
.04	40	.4	5.1	8.5	12.0	15.4	18.9
.06	60	.4	8.0	12.0	16.1	20.1	24.2
.08	80	.4	10.5	15.0	19.6	24.1	28.7
.10	100	.4	13.0	18.0	23.1	28.1	33.2
.12	120	.4	15.5	21.0	26.6	32.1	37.7
.13	130	.4	16.8	22.6	28.4	34.2	40.0
.03	30	.5	5.8	9.4	13.0	16.6	20.2
.04	40	.5	8.1	11.9	15.7	19.5	23.3
.06	60	.5	12.8	17.8	22.8	27.8	32.8
.08	80	.5	16.9	22.7	28.5	34.3	40.1
.10	100	.5	20.9	27.5	34.1	40.7	47.4
.12	120	.5	25.0	32.4	39.9	47.3	54.8
.13	130	.5	27.1	34.9	42.8	50.6	58.5
.03	30	.6	8.0	12.0	16.1	20.1	24.2
.04	40	.6	11.2	15.9	20.6	25.3	29.9
.06	60	.6	17.6	23.5	29.5	35.4	41.4
.08	80	.6	23.2	30.3	37.4	44.5	51.5
.10	100	.6	28.8	37.0	45.2	53.4	61.6
.12	120	.6	34.4	43.7	53.1	62.4	71.8
.13	130	.6	37.3	47.2	57.1	67.0	76.9
.03	30	.65	9.1	13.3	17.6	21.8	26.1
.04	40	.65	12.8	17.8	22.8	27.8	32.8
.06	60	.65	20.0	29.3	38.6	47.9	57.3
.08	80	.65	26.4	36.2	46.0	55.8	65.5
.10	100	.65	32.8	43.0	53.2	63.4	73.7
.12	120	.65	39.2	49.9	60.6	71.3	81.9
.13	130	.65	42.4	53.3	64.2	75.1	86.1

[1] Add idling horsepower = 4.43 horsepower; add 2 horsepower for carriage pull on the saw.
[2] Use specific gravities for oven-dry material based on volume at time of test as given in U. S. Department of Agriculture Bulletin No. 479.

TABLE 4.—CUTTING HORSEPOWER EXCLUSIVE OF MACHINE LOSS HORSEPOWER[1]
(r.p.m. of saw = 600, r.p.m. of torque meter = 1,200)

Hp. = Torque × 0.01904

Bite per tooth	Carriage feed for a 40-tooth saw	Specific gravity[2]	Depth of cut—Inches				
			10	12	14	16	18
Inch	Ft. per min.		Hp.	Hp.	Hp.	Hp.	Hp.
0.03	60	0.3	1.9	6.5	11.1	15.7	20.2
.04	80	.3	3.0	7.8	12.6	17.4	22.2
.06	120	.3	5.4	10.7	16.0	21.3	26.5
.08	160	.3	7.1	12.7	18.3	23.9	29.6
.10	200	.3	8.8	14.8	20.8	26.7	32.7
.12	240	.3	10.5	16.8	23.1	29.4	35.8
.13	260	.3	11.4	17.9	24.4	30.9	37.3
.03	60	.4	4.9	10.1	15.3	20.5	25.6
.04	80	.4	7.7	13.4	19.2	24.9	30.7
.06	120	.4	13.7	20.6	27.6	34.5	41.5
.08	160	.4	18.1	25.9	33.7	41.5	49.3
.10	200	.4	22.5	31.1	39.8	48.4	57.1
.12	240	.4	26.9	36.4	45.9	55.4	65.0
.13	260	.4	29.0	39.0	49.0	59.0	69.0
.03	60	.5	7.8	13.5	19.3	25.0	30.8
.04	80	.5	12.3	18.9	25.6	32.2	38.9
.06	120	.5	22.0	30.6	39.2	47.8	56.4
.08	160	.5	29.0	39.0	49.0	59.0	69.0
.10	200	.5	36.0	47.4	58.8	70.2	81.6
.12	240	.5	43.0	55.8	68.6	81.4	94.3
.13	260	.5	46.6	60.1	73.6	87.1	100.7
.03	60	.6	10.8	17.1	23.5	29.8	36.2
.04	80	.6	17.0	24.6	32.2	39.8	47.4
.06	120	.6	30.4	40.7	51.0	61.3	71.5
.08	160	.6	40.1	52.3	64.5	76.7	88.9
.10	200	.6	49.8	63.9	78.0	92.1	106.3
.12	240	.6	59.5	75.5	91.6	107.6	123.7
.13	260	.6	64.3	81.3	98.4	115.4	132.5
.03	60	.65	12.3	18.9	25.6	32.2	38.9
.04	80	.65	19.4	27.5	35.6	43.7	51.7
.06	120	.65	34.5	45.6	56.7	67.8	78.9
.08	160	.65	45.5	58.8	72.1	85.4	98.7
.10	200	.65	56.5	72.0	87.5	103.0	118.6
.12	240	.65	67.5	85.2	102.9	120.6	138.4
.13	260	.65	73.1	91.9	110.7	129.5	148.4

[1] Add idling horsepower = 8.85; add 4 horsepower as maximum for carriage pull on the saw.
[2] Use specific gravities for oven-dry material based on volume at time of test as given in U. S. Department of Agriculture Bulletin No. 479.

TABLE 5.—CUTTING HORSEPOWER EXCLUSIVE OF MACHINE LOSS HORSEPOWER[1]
(r.p.m. of saw = 450; r.p.m. of torque meter = 900)

Hp. = Torque × 0.01428

Bite per tooth	Carriage feed for a 40-tooth saw	Specific gravity[2]	Depth of cut—Inches				
			10	12	14	16	18
Inch	Ft. per min.		Hp.	Hp.	Hp.	Hp.	Hp.
0.03	45	0.3	1.8	5.5	9.3	13.0	16.8
.04	60	.3	2.6	6.5	10.4	14.3	18.3
.06	90	.3	4.4	8.7	13.0	17.2	21.5
.08	120	.3	5.8	10.3	14.9	19.4	24.0
.10	150	.3	7.2	12.0	16.8	21.6	26.5
.12	180	.3	8.6	13.7	18.8	23.9	29.0
.13	195	.3	9.3	14.5	19.8	25.0	30.3
.03	45	.4	.46	8.9	13.2	17.5	21.9
.04	60	.4	6.7	11.4	16.2	20.9	25.7
.06	90	.4	11.1	16.7	22.3	27.9	33.6
.08	120	.4	14.6	20.9	27.3	33.6	40.0
.10	150	.4	18.1	25.2	32.3	39.3	46.4
.12	180	.4	21.6	29.4	37.2	45.0	52.8
.13	195	.4	23.5	31.6	39.7	47.8	55.9
.03	45	.5	7.3	12.1	17.0	21.8	26.7
.04	60	.5	10.7	16.2	21.8	27.3	32.9
.06	90	.5	17.8	34.7	31.7	38.6	45.6
.08	120	.5	23.5	31.6	39.7	47.8	55.9
.10	150	.5	29.2	38.4	47.7	56.9	66.2
.12	180	.5	34.9	45.3	55.7	66.1	76.5
.13	195	.5	37.8	48.7	59.7	70.6	81.6
.03	45	.6	10.1	15.5	20.9	26.3	31.8
.04	60	.6	14.7	21.0	27.4	33.7	40.1
.06	90	.6	24.6	32.9	41.2	49.5	57.9
.08	120	.6	32.5	42.4	52.3	62.2	72.1
.10	150	.6	40.4	51.8	63.3	74.7	86.2
.12	180	.6	48.2	61.2	74.2	87.2	100.3
.13	195	.6	52.1	65.9	79.7	93.5	107.4
.03	45	.65	11.5	17.2	22.9	28.6	34.3
.04	60	.65	16.8	23.5	30.3	37.0	43.8
.06	90	.65	28.0	37.0	46.0	55.0	64.0
.08	120	.65	36.9	47.7	58.5	69.3	80.1
.10	150	.65	45.8	58.4	71.0	83.6	96.1
.12	180	.65	54.7	69.0	83.4	97.7	112.1
.13	195	.65	59.2	74.4	89.7	104.9	120.2

[1]Add idling horsepower = 6.64 horsepower; add 3 horsepower for carriage pull on the saw.
[2]Use specific gravities for oven-dry material based on volume at time of test as given in U. S. Department of Agriculture Bulletin No. 479.

failed to cut a true line and the torque increased.

In cutting frozen wood compared with unfrozen material a slight trend of increased torque for unfrozen material was registered. This was contrary to test results relative to other physical properties, such as strength in bending, shear, and the like, and implied that the very real difficulty in sawing certain species when frozen may be due to other than force requirements.

In climb cutting where the saw direction of running was reversed and the saw turned around so it entered the bottom and emerged at the top, approximately 2.7 times the torque for cutting under normal conditions were indicated for the reverse-direction cutting.

With respect to the effect of saw diameter, as between 60- and 48-inch diameter saws cutting with similar feeds per tooth, the 25 percent larger 60-inch saw required between 24 and 36 percent more torque to a saw a 19-inch depth.

The effect of knots was as follows: In sawing Douglas fir knots comprising 40 percent of the cutting arc, the torque increased 70 percent over that registered in cutting clear areas indicating approximately a threefold increase in force requirements for a knot as compared to a clear section.

Gullet space requirements indicated by the tests are that gullet space ratio (profile area) to wood removed for the 2½ style in Douglas fir was 2.38 to 1; for the B style in ash and oak 2.5 to 1.

For similar feed rates per saw revolution torque was influenced more by the number of teeth in the saw than by style of tooth, increasing as the number increased.

References

(1) Foyster, J. R., 1947. Modern Mechanical Saw Practice: Practical Survey of Sawmilling Machinery and Methods and Maintenance. 274 p., illus. Crosby Lockwood & Son, Ltd., London.

(2) Harris, Philip, 1946. Handbook of Woodcutting. 44 p., illus. Dept. Sci. and Indus. Res., London.

(3) Harris, Philip, 1947. Mechanics of Sawing: Circular Saws. Wood (London) 12: 159–163, illus.

(4) Kaioukowa, M. W. and Konjuchow, D. N., 1934–35. Cutting of Timber: Research on Round Saws and the Process of Cutting With Them. Wood Working Indus. U.S.S.R. (Moscow) 1934, 11:36–55; 1935, 1:29–39. Translated by R. J. Huzarski.

(5) Kollmann, Franz, 1936. Technologie des Holzes. 764 p., illus. Julius Springer, Berlin.

(6) Meyer, Max, 1926. Untersuchungen über die den zerspanungsvorgang mittels holzkreissägen beeinflussenden faktoren. In Sachsenberg, E., Ausgewählte arbeiten des lehrstuhles für betriebswissenschaften in Dresden, v. 3, p. 90–117, illus. Julius Springer, Berlin.

Ills Besetting the Furniture Industry*

Clyne Crawford

President, Crawford Furniture Manufacturing Corporation, Jamestown, New York

Some of the problems faced by the furniture industry are described. The waste and difficulty encountered in the utilization of poorly manufactured lumber produced by small mills is emphasized. A second important problem dealt with is that of drying to specified moisture contents and maintaining desired moisture equilibria during manufacture in order to minimize checking, warping, etc.

AS I understand this assignment, I have the privilege of raising the issues of some of the main production problems in the manufacture of furniture without the necessity of offering solutions for these problems, which makes the job quite simple. The furniture industry has progressed a great deal since World War II in more efficient manufacturing methods, with the result that some of our old problems have become magnified and more pronounced because they retard some of the progress we had planned.

Much has been said about wood waste and the utilization of poorer grades. The greatest immediate saving of lumber waste would be to prevent excellent grades of good lumber from being wasted due to poor manufacturing. With the "conveyorization" of dimension mills in furniture plants the waste due to mis-cuts is greater than under older woodworking methods. Some years back we tried to use these miscut boards by constant adjustment of the rough planer, but with these planers fed from conveyors, wedge-shaped lumber ties up the entire production line and cannot be used. Uniform raw material is essential for high speed production.

It is heartbreaking to see high-grade 14-foot boards sawed to 1½ inch thickness on one end and ¾ inch on the other. Yet this is very prevalent among the small mills, which account for a sizable total footage of our supply. It is difficult for the small mills to comprehend the importance of this. Some organization, probably the furniture manufacturers, should initiate an educational program to convince the small mills that inefficient and poorly maintained equipment is the most expensive operation they can have. It is a waste of our Nation's natural resources to engage in that type of lumber operation. Yet this waste is as great or greater now than at any time in our experience.

Someone is always trying to take the mystery out of lumber drying, but to me it is still a mystery. We use cherry and hard maple primarily. The problem of checking and open joints is not so great with the softer woods, such as cherry, but I do not think I will ever know for sure what causes the open joints in rock maple one week or why the joints stay together and give us a breathing spell for the next several weeks. Most of these open joints are so fine that they cannot be seen until the merchandise is finished. The problems of drying, sawing, and gluing seem so closely related to open joint trouble that it is difficult to be sure of the cause.

We most carefully space our stickers on 12-inch centers in accurate rows of a template. We use the forced draft ventilation type of dry kiln with semi-automatic control of both temperature and humidity. We test the lumber carefully when it comes out of the dry kiln and put it in a dry storage shed controlled for heat and humidity for a week and then again test the lumber for moisture content before sending it to the saws.

We rip saw the lumber with Tungsten carbide tipped blades to make sure we get a uniform saw joint as we glue after the rip sawing operation. We check the bearings of the rip saws regularly to make sure there is no play there. We use a urea resin glue and have the dimension mill equipped with automatic humidifiers to avoid distortion of ripped edges due to humidity changes overnight. We have installed new boilers to make sure we have sufficient constant steam pressure for our dry kilns, lumber storage room, and gluing ma-

* Presented by title only.

chine. In spite of all our precautions we can run into open joints every now and then and we are never certain as to what caused it. I hope the research now being done on glues will turn up some answers, but the answers probably will not be simple as they must consider the type and characteristics of lumber used as well as the method of drying, moisture content, etc. I know any research on these problems will be greatly appreciated by the industry.

We had a rather interesting experience recently. We assumed because the lumber was at a moisture content of 7 percent when it reached the slash saws that it did not change much until becoming the finished product. I am not sure whether we assumed that, or just did not think at all, but one day we made a check of the moisture content as the lumber progressed through the plant. We found it was 5 percent before it was fully machined, 4 percent in the cabinet room and 2 percent in the finishing room. Then we installed automatic humidifiers throughout the plant.

Now moisture is automatically added if the department is too dry but in the summer time when the humidity is too high we do not know how to take the moisture out of the atmosphere. If someone could find a chemical that would do this easily I know many of us would be grateful.

These are the production problems that come most readily to mind. Unfortunately it is much easier to state them than to solve them.

Discussion

E. George Stern (Virginia Polytechnic Institute): The reasons to explain failure of panel stock may be manifold. Usually, a careful study of existing conditions will bring to light definite causes of the difficulties encountered. To mention just a few:

During an investigation of conditions at a plant, it was found that a kiln operator was instructed to dry his lumber to a moisture content of five percent. His interpretation of the instruction was that anything below five percent would be perfect.

At another plant, the determination of moisture content was found to be inaccurate because the balance was not level and because the volatiles were included in the computed amount of moisture.

At another plant, the relative humidity was determined with instruments requiring a certain amount of air flow around the wet pulp. A fan should have been installed to provide such an air flow.

During the absence of the regular kiln operator of a plant, green and air-dried stock was inadvertently placed in the same kiln and the kiln load dried according to the schedule for green lumber.

That panel stock which was accidentally placed in front of heating units was dried out excessively and not reconditioned to proper moisture content.

Top panels of tightly stacked stock piles dried out excessively and, although warped, were used in standard assembly.

So far it has been possible for the writer to find the causes for every failure upon careful examination of given conditions. It may be worthwhile for a plant encountering difficulties such as those described in the paper to have a careful inspection made by a qualified outside engineer who can look at given conditions with an unbiased eye.

Mr. Crawford: When Mr. Stern says causes for every joint failure can be found upon careful examination of given conditions, he may be begging the question a little bit, if I understand his wording correctly. Unfortunately conditions change so rapidly in a furniture plant due to the necessity of powerful dust collecting systems rapidly removing air that has been humidified or otherwise conditioned, that conditions are never static. They often change within the day.

We recently brought in a lecturer on wood and its joint failures. While he gave us a great deal of good advice, unfortunately the lumber charge brought through under his supervision gave us more trouble than any we had had in the last few years. However, we still believe in engaging consultants from time to time and will maintain this policy in the future.

The fact that the National Furniture Manufacturers Association sponsored a University of Michigan research project to study wood bond-

ing under various conditions, shows that the problem is still common to many progressive manufacturers in the furniture industry.

We recently found that some saws not more than two years old were not making a square joint. Since we glue up from the rip saws, this was serious. The degree it was out of square could not be observed by an ordinary square, yet it was serious enough to leave a hair line joint observable when the piece was finished. We immediately bought new saws of another make.

Those corrections are always helpful but it is still my belief that a great deal more must be learned through research about the bonding of different species of lumber under various conditions before we can entirely eliminate the expense of open joints.

TECHNICAL SESSION III

Tuesday, May 3, 1940, 9:00 A. M.

General Subject: Chemical Utilization of Wood and Wood Preservation

Chairman: Kenneth G. Chesley, Director of Research, Crossett Lumber Company, Crossett, Arkansas *(South-Central Regional Board Member, FPRS)*

Recorder: Frederick H. Vogel, Professor, School of Forestry, Alabama Polytechnic Institute, Auburn, Alabama *(Trustee, Florida–Georgia–Alabama Section, FPRS)*

FOREST PRODUCTS RESEARCH SOCIETY

Utilization of Redwood Bark

Harry F. Lewis

Research Associate, The Institute of Paper Chemistry, Appleton, Wisconsin

This paper summarizes the work done to date on the utilization of redwood bark by The Institute of Paper Chemistry and The Pacific Lumber Company. The mechanical separation of the bark into "fiber" and "dust" fractions and the chemical and physical properties of the fractions are given. Experiments on the use of bark fiber in low quality papers, as fillers, for plastics, loose-fill insulation, and textiles, are described. The use of the "dust" fraction as a filler for plastics and as a substitute for peat moss and problems involved in such use are given. The low methoxyl content of redwood bark lignin as compared to the methoxyl content of wood lignin and the production of sodium palconate from the acid fraction of the bark are likewise described.

Introduction

AN INCREASING interest can be noted in the chemistry and technology of bark. Although no attempt will be made in this paper to review the recent work in the field, reference can be made to the report on the "Chemistry and Utilization of Bark" published by the Northeastern Wood Utilization Council, January, 1949, and to articles by Kurth *(1)*, Segall and Purves *(2)*, and Wacek and Schön *(3)*. References will be found to the work of Zellner, Zetzsche, Sharkov, and others in the above articles.

Redwood bark may be recovered in relatively large amounts as one of the by-products of the redwood lumbering operation. The following report describes many of the studies which have been made by The Pacific Lumber Company and The Institute of Paper Chemistry, looking toward the complete utilization of this bark. Fritz *(4)* has estimated that the bark present on the merchantable timber in a redwood operation amounts to approximately 23.6 cords per acre. The figures have been found to vary over a considerable range depending on the size of the trees and differences in individual trees. In one operation, a mill cutting 500,000 board feet of redwood lumber per day recovered up to 282 cords of bark as a by-product. Not all this bark is actually recoverable at the mill, for a portion of it is lost in the general processing operation; on the other hand, there would be a considerable quantity of bark which could be salvaged from the nonmerchantable wood. The actual tonnage at this mill would be roughly 12,000 to 14,000 tons a year (airdry basis). The disposal of such an amount of bark without any utilization whatever at the mill would be quite a problem, for redwood bark is difficult to burn, and there is no other way of consuming it at the mill. One alternative is to bark the wood after the tree is felled and bring in only the barked logs. This means the waste of a large amount of valuable fiber and nonfibrous organic material. Another alternative is to develop satisfactory uses for the major portion of it.

Anatomical Units of Redwood Bark

Redwood bark is made up chiefly of five types of cells: sieve cells, phloem parenchyma, phloem ray parenchyma, fibers, and cork cells. The sieve cells appear to comprise a majority of the cells in the inner bark. The fibers are adapted to the mechanical strengthening of the bark structure. They are arranged in tangential uniseriate rows which seem to occur with some regularity. It is difficult to determine the frequency of formation of these rows in the older sections of the bark, but the indications are that one row of fibers is formed each year. The fibers are responsible for more than 25 percent of the weight of the bark; their average length is between 6 and 8 mm., although a few are in excess of 10 mm. with no significant difference in the length in young and old bark. In the outer bark, the cork and ray parenchyma cells appear to be full of a reddish-brown alkali-soluble material, acidic in nature. To a much smaller degree this or a related material is on or in the walls of the other cells.

A detailed description of the anatomy of redwood bark has been published by Isenberg *(5)*. Technical articles on the chemical

composition of the bark have likewise been published by Brauns, Lewis, and co-workers *(6, 7)*. In view of the extended discussion on the physical and chemical structure of redwood bark by these men, no attempt will be made to review the material in detail.

How Bark Components Are Separated

A description of the process for separating the fibrous material in the bark from the remaining structure may prove interesting. The log with its bark is brought to The Pacific Lumber Company mill at Scotia (generally by rail), unloaded into the pond, and floated to the bark plant where the bark is removed in large slabs. These slabs are run through hammer mills where the walls of the rather brittle short cells break down, resulting in a crude separation of ropy fiber bundles and finely divided dust. A modified textile operation is used to separate the coarse fiber and the dust. In this operation the mixture of the fiber and the bark dust from the hammer mill is delivered to a magazine feed, the vertical apron of which permits a volumetric feeding to three cone willow dusters which screen the larger portion of the dust and broken fiber ends resulting from shredding from the fibrous fraction. From the cone willow operation, the fiber is delivered by air suction over a textile condenser, then to a textile lumper picker which refines the fiber still further and, finally, over a second condensing operation. From this operation the fiber goes to a tunnel-type conveyor drier about 120 feet in length. From the dry end of the drier, the fiber is delivered by air to a third condenser operation and is then fed to a volumetric feeder from which it passes to its subsequent processing operation and baling for shipment. The short fibers and dust from these condensing operations pass through a cone cylindrical screen operation for dust removal. The fiber fraction from this latter operation is then fed to a mechanical air separator, the fines from which constitute a superrefined bark product termed "Fiber A". The bark dust end product represents both the short, thin-walled cells and short pieces of fiber in a degraded condition which result from these various operations. In reviewing the further studies, it is necessary to refer either to the fiber fraction or to the dust fraction; the *fiber fraction* is the coarse product from the condenser after drying, the *dust* is the fine fraction from the mechanical air separator.

Chemical Characteristics

A conventional analysis of either the fiber or dust by the Klason method points to an extraordinarily high "lignin" content. Further investigation, however, of the so-called "lignin" reveals the fact that a large part of the material determined as lignin is, in truth, not lignin at all. The principal constituent of this "lignin" is easily soluble in hot, dilute caustic solutions. It differs from the lignin in the wood in being practically free of methoxyl and in having significantly more phenolic hydroxyls and carboxylic groups. In addition to the "bark lignins," the bark fiber contains a certain quantity of pectic acid and cellulose but only a small amount of extractives. Successive extractions of the bark fiber reveal the presence of approximately 0.2 percent of ether-soluble material, 2.5 percent of alcohol-soluble material, and 4.5 percent of hot water-soluble material. Both the alcohol and water fractions contain small amounts of tannins and phlobaphene in an amount not in excess of 2 percent. Larger relative volumes of hot water will dissolve up to 15 percent of the bark. The fiber contains about 7 to 8 percent of pentosans and approximately 60 percent of reducing sugar after hydrolysis, which (calculated to cellulose) would indicate the presence of about 54 percent of cellulose. Actually, the value includes lesser amounts of other polysaccharides yielding reducing sugars on hydrolysis, such as mannan and xylan. The remainder, 41.8 percent in one sample by actual test, consists of the "lignin" fraction. Whereas the principal component of the "lignin" (the low methoxyl acid body) makes up three quarters of the fraction, the remainder seems to be a bark lignin very similar to redwood lignin.

Pulping Tests

One of the first impulses of anyone interested in the manufacture of pulp and paper would be to study redwood bark fiber as a papermaking material. This has been done. Cooking by either the sulfite or soda process does not yield a delignified pulp. The prin-

cipal result of either process is to dissolve the acid constituent. The black liquors are composed mainly of the sodium salts of either the acid or the sulfonated acid (in the sulfite cook). The true lignin constituent is removed very slowly even on recooking the pulp. A modification of an alkaline cooking process was employed in preparing the bark fiber pulp which was converted into the Fibrite separators for use in nonspill plastic-type batteries so popular during World War II in the "Walkie-Talkie" and in many electronic instruments; in this process a mild cook removed a large amount of the pectin material and a portion of the organic acids, and the separator sheet was formed on a Fourdrinier machine. Such a sheet is very porous and is not particularly strong in terms of a conventional sheet of the same caliper.

Further papermaking experiments were carried out with unpulped Fiber A, using mixtures of 85 percent of bleached soda pulp and 15 percent of Fiber A. A sheet of paper made from 100 percent soda pulp would be a relatively weak sheet, and any desirable effect of the bark fiber was certain to be evidenced by the properties of the resulting sheet. The bark fiber in this amount does not lower the bursting strength of the paper; in fact, it increases the tear strength markedly. In a second set of experiments, sheets were made from 65 percent of unbleached sulfite pulp, 20 percent of groundwood pulp, and 15 percent of bark fiber; these were compared with sheets made from 80 percent of sulfite pulp and 20 percent of groundwood pulp. The strength tests indicate that the introduction of 15 percent of bark fiber instead of the same amount of sulfite pulp does not greatly reduce the strength of the sheet. In the next series of experiments, studies were made of furnishes which might be used in a second-grade hanging stock. Such stock is made up of groundwood and unbleached sulfite, generally to the extent of 80 percent of groundwood and 20 percent of unbleached sulfite. The complete replacement of the sulfite by bark fiber results in the production of paper which is weaker than the 100 percent groundwood furnish alone, although it does have a somewhat better tearing strength. The replacement of half the sulfite by bark fiber produces a sheet which is stronger than 100 percent groundwood but weaker than the 80–20 groundwood-sulfite sheet. It does not seem possible to substitute bark fiber for unbleached sulfite in a No. 2 hanging stock and, at the same time, produce a paper having the same characteristics as furnishes containing unbleached sulfite and news groundwood alone.

Characteristics of the Bark as a Plastic Filler

Redwood bark fiber has been suggested as a filler for plastics. Bark fiber sheets of a thickness of 0.05 inch have been impregnated with a phenol-formaldehyde low-pressure molding resin for use in the manufacture of low-pressure laminates. A panel prepared by laminating six sheets of this paper impregnated with 40 percent of resin at a pressure of 500 psi. and 300° F. has a specific gravity of 1.36, a tensile strength of about 15,000 psi., a modulus of elasticity (in psi. $\times 10^6$) of 1.54, an edgewise notched Charpy impact of 0.54 ft.-lb. per inch of notch, and a water absorption of 1.27 percent. The fibrous material has also been used as a filler in molding powders, employing a variety of thermosetting and thermoplastic resins. The products obtained are either about the same or slightly better than those containing an equal quantity of wood flour filler. Since the cost of the fiber is several times that of wood flour, such application would be uneconomical unless some method is developed for utilizing the product to better advantage.

Redwood Bark as Insulation

One of the oldest uses for redwood bark fiber has been as loose-fill insulation. The material supplied for this purpose represents a shredded product of fairly long fiber bundles still containing some of the short-fibered cells which adhere to the bundles. These do not interfere with the efficiency of the loose-fill insulation. The material is applied at an average density of approximately 5 lb. per cu. ft. Very little settling results at this density, even over long periods of time and under fairly severe vibrating conditions. These properties make it useful for cold storage insulation and for house insulation. The thermal conductivity per hour per inch of thickness per square foot per degree Fahrenheit temperature difference has been

found to be 0.255 at a density of five pounds. This compares favorably with low density cork board and with balsam wool and glass wool, although these latter materials have a much lower density. Although the redwood bark fiber itself is resistant to burning, it has been found possible to improve the fire-resistant characteristics by the addition of a fireproofing treatment consisting of ammonium salts.

Textiles, Bats, and Filters

The use of redwood bark fiber in textiles is limited by the fact that the fiber has a dark reddish-brown color and, for this reason, it can be used only with materials having a dark shade. Textile mill runs have been carried out with blends of Fiber A and wool. Amounts up to 50 percent of bark fiber can be mixed, particularly with low-grade, re-used wool fiber, and the cloth produced appears to be very satisfactory for certain applications—as in inexpensive men's suiting, overcoats, mackinaws, low-priced blankets, and other products.

A large amount of redwood bark fiber in combination with cotton has been used for the manufacture of bats for mattresses and related products. Mattress filling has been made from 60 percent cotton and 40 percent Fiber A. Tests made on the product as a mattress filling in a commercial testing laboratory have shown that the best results are obtained with this blend. They indicate that the addition of the redwood bark fiber to the cotton has two effects—first, the bark fiber adds to the resiliency of the product and, second, the bark fiber-cotton mixture picks up moisture more slowly and releases it more rapidly than does cotton alone. This is a definite advantage, particularly where the mattresses are used under humid conditions. On the other hand, the addition of 40 percent of the bark fiber to the cotton makes it necessary to add 5 to 15 percent additional weight in order to produce the same bulk of filling.

A somewhat similar mixture of cotton and Fiber A has been employed as oil filters for diesel engines. In this case, waste stripper cotton has been used. The physical characteristics of the fiber, together with the resiliency of the blend, give a good flow factor and satisfactory filtering performance.

Bleaching Trials

Attempts have been made to improve the color of redwood bark fiber. The chemically pulped fiber is bleached only with difficulty by conventional bleaching agents. This might be expected in view of the difficulty encountered in attempting to delignify these bark fibers completely. However, they can be bleached easily by sodium peroxide or sodium chlorite. The resulting white fiber from the sodium chlorite operation is more brittle than the wood fiber of the same appearance and method of purification; it is not attractive as a source of either textile or papermaking material in the conventional sense. Unfortunately, in attempting to improve the color of the fiber by removing or chemically modifying the colored compounds, the desirable physical structure of the fiber is impaired. The pectin in the fiber is soluble in hot water, in caustic, and in the ordinary bleaching solution. Other alkali-soluble carbohydrates will also be removed by bleaching agents. Efforts to restore the desirable properties through the addition of softening agents have been only partly successful.

Acid Resistance of the Fiber

Although the insulating characteristics of the bark fiber make possible many interesting applications, it would seem that applications where low-price acid-resisting fibers are used might be developed. The refined fiber behaves as though it were completely surrounded by a continuous film of lignin. As an illustration, the use of redwood bark fiber in the Fibrite separators is a case in point. Here it must not only withstand the action of sulfuric acid at elevated temperatures for long periods but also the action of oxygen and hydrogen under the same conditions. Actual tests show only a relatively small loss in alpha-cellulose after service.

Characteristics of the Dust

More than half of the bark separated commercially is the so-called "bark dust." The greater percentage of this dust dissolves quickly in four percent caustic at 160° C. and, from this alkaline solution, no precipitate is obtained with carbon dioxide in direct contrast to the behavior of the lignin in alkaline black liquors from the soda or kraft wood pulping proc-

esses. On acidification with hydrochloric acid, a voluminous brown precipitate is formed. When this is further purified, it shows a methoxyl content of less than 0.1 percent. Under these same conditions, the lignin isolated from an alkaline cook of the wood would show about 15 percent of methoxyl. The active groups are largely carboxyls and hydroxyls, with twice as many hydroxyl as carboxyl groups. If a minimum molecular weight of 835 (based upon the phenolic hydroxyl content) is assumed, there would be three carboxyl groups, two alcoholic hydroxyls, and four phenolic hydroxyls. This would seem to indicate other possible uses for "Palconic acid." In addition to the acid fraction, the bark dust contains approximately ten percent of a hot water-soluble product which is almost entirely pectin. Analysis of this pectin by Dr. Anderson of the University of Arizona shows the presence of 76 percent uronic acid, 25.9 percent pentosans, and 0.53 percent methoxyl. The rotation in two percent ammonium hydroxide is +233°. The value is similar to other values for pectic acid. In addition, the broken ends of the fibers yield cellulose. It must be kept in mind that, with a natural product of this type, one is not dealing with a uniform and homogeneous compound but rather with a product of varying molecular size which may change significantly in composition during isolation. Among the extractives in bark dust will be found small amounts of water- and alcohol-soluble tannin, phlobaphenes, and related materials, together with about 0.6 percent of waxy material soluble in trichloroethylene, benzene, petroleum ether, and acetone.

Possible Dust Applications

Some work has been carried out where the bark dust has been compared with peat moss. In the first experiments, the two products were compared for variations in composition. The results show the bark dust to contain slightly less nitrogen, about the same very small amounts of potassium, about twice as much phosphorous, and a fourth as much calcium. The water extract from the bark dust was appreciably more acid than that from the peat; both were decidedly acid.

A comparative test for so-called humic acid by the Eller method *(8)*, using two percent sodium hydroxide solution at 20° C., yielded 7.5 percent "humic acid" from the bark and 11.9 percent from the peat moss. At higher concentrations and for longer times, the recoveries are about the same for the two products. In actual use, the bark product seems longer lived than the peat moss.

The humic acids characteristically bind ammonia which cannot be removed by cooking with strong caustic. It has been shown that bark dust and peat moss bind about the same amount. In one bark product, better than ten percent of ammonia was bound and, of this, 3.1 percent represented ammonium plus amide nitrogen, the rest being combined in some other form. A final property of interest is the water-binding capacity of mulches. On a volume basis, bark dust is twice as dense but has only one third the water-holding capacity of the peat moss. These are very preliminary experiments.

Bark dust may serve to function by conditioning the soil, permitting improved drainage and availability of oxygen; at the same time, it contains small amounts of minerals, holds a certain amount of water, and yields some soluble organic material to the soil. Because of its greater stability, it might be expected to remain in the soil for longer periods of time than does peat moss.

On destructive distillation a ton of bark dust yields about 900 pounds of charcoal and 52 pounds of tar. More than half the tar is a mixture of higher fatty acids and lower phenols; in addition, about 15 pounds of neutral oils and a pound of nitrogen bases can be recovered per ton of dust. The neutral oil fraction contains hydroacetylacetone.

The dust may be converted to derivatives of the acidic constituent having some potentiality as colloidal agents. A pilot plant has been set up at The Institute of Paper Chemistry for manufacturing sizable amounts of either the sodium salt of the acid under the trade name of Sodium Palconate, of the free acid itself, or modifications of these products. Kottwitz and Forman *(9)* have described the pilot plant and its operation. In brief, Sodium Palconate is made by cooking either with alkali or with other suitable reagents and the salts are converted to the free acids by resin exchange. The

solid acids are also concentrated and spray dried. Sizable amounts of any of these products are available for testing.

Among the potential uses of Sodium Palconate is as an oil well drilling mud additive. Although the actual data on Sodium Palconate as a drilling mud additive have not yet been published, many tests have been made which show that this product, either in the form of Sodium Palconate or as a recently developed derivative, may find a rather wide use in certain drilling operations as a replacement for quebracho. These materials have been found to control viscosity, water loss, and gel strength in many types of muds. Another related use is in the flotation of fluorspar from calcium carbonate and silica where oleic acid is added as a flotation agent and either quebracho or the Palconates serve to depress both calcite and silica by acting as a deflocculating agent.

It is not possible at this time to review other applications for derivatives of the bark acid or for the bark fiber. Studies are actively in progress which appear to offer hope for the more effective utilization of redwood bark.

I should like to close with the comment that research looking to the development of uses for the by-products or wastes of our forest products operations is neither spectacular from a scientific standpoint nor does it often point the way to hidden gold. We are working with substances which we cannot classify chemically because of the difficulties involved in their purification and, because of this, in much of our work, we are groping in the dark towards our goal. We always have the probable competition from the chemical industry for the markets we may develop or hope to serve, but we have the assurance that the fundamental and applied research we do today will be useful tomorrow, provided we see to it that our forests are not destroyed.

Literature Cited

(1) Kurth, E. F.: The Chemical Composition of Barks. Chem. Revs., Vol. 40, pages 33–49. (1947)

(2) Segall, G. H., and Purves, C. B.: Chemical Composition of Wood Barks. Pulp Paper Mag. of Canada, Vol. 47, pages 149–162. (Feb. 1946)

(3) Wacek, A. V., and Schön, A.: The Chemical Composition of Tree Barks. Holz Ruh- u. Werkstoff, Vol. 4, pages 18–26. (1941)

(4) Fritz, Emanuel.: Breakage Reduction in Felling Redwood. J. Forestry, Vol. 36, pages 405–410. (1938)

(5) Isenberg, I. H.: The Anatomy of Redwood Bark. Madraño, Vol. 7, No. 3, pages 85–91. (July 1943)

(6) Brauns, F. E., and Lewis, H. F.: The Nature of the Lignin in Redwood Bark. Paper Trade J., Vol. 119, No. 22, pages 34–38. (Nov. 30, 1944)

(7) Lewis, H. F., Brauns, F. E., Buchanan, M. A., and Kurth, E. F.: Chemical Composition of Redwood Bark. Ind. Eng. Chem., Vol. 36, pages 759–764. (1944)

(8) Eller, Wilhelm: Studies of Humic Acids. IV. Preparation and Properties of Synthetic and Natural Humic Acids. Ann., Vol. 431, page 159. (1923)

(9) Kottwitz, F. A., and Forman, L. V.: Sodium Palconate Production. Ind. Eng. Chem., Vol. 40, pages 2443–2450. (1948)

Discussion

A. B. Recknagle (St. Regis Paper Company): Why have no other redwood operators followed the lead of the Pacific Lumber Company in utilizing bark?

Dr. Lewis: The Pacific Lumber Company has spent a considerable amount of money in developing processes and equipment for producing bark fibers essentially free from the so-called dust. In addition, they have had to develop uses and sales outlets. Even today their bark processing operations might still be looked upon as experimental, although the uses which have been developed have been sound. Why other companies do not utilize the bark, I do not know; it is possible that the market has not been sufficiently attractive.

Robert M. Boehm (Masonite Corporation): Will you please comment on the problem of dust removal from redwood bark fibers and give us an estimate of what percent of bark is fiber?

Dr. Lewis: In the general operations of the Pacific Lumber Company, essentially half of the bark is recovered as *loose fill insulation fiber;*

the rest is dust. The actual content of fiber in the bark by weight probably runs about 25 percent, although it is very hard to give an exact figure. The dust is recovered in cyclones and in dust filters, but it is still difficult to condense it completely.

Kenneth G. Chesley (Crosset Lumber Company): About how many tons of redwood bark are there per acre in relation to the total weight of wood per acre?

Dr. Lewis: Professor Fritz has made a study of 732 trees on 31 acres. His figures show that the trees yielded 3,774,047 bd. ft. Spaulding (121,740 bd. ft. per acre) and 730 cords of bark (23.6 cords per acre), or 1 cord of bark per 5150 bd. ft. of logs. Trees under commercial size were not included in the study. The yields were computed from dimensions and were not checked by field piling. Undoubtedly other studies would yield still different results.

Irving H. Isenberg (Institute of Paper Chemistry): It may be well to point out that many species of trees do not contain true fibers in their barks. Among our softwoods, the cedars, bald-cypress, redwood and bigtree do have fibrous barks. Certain hardwoods, such as basswood, also are fibrous in nature. However, the barks of various species available in continued large amounts may contain interesting chemical material and, hence, should be explored much more broadly and thoroughly than they have been to date.

Dr. Lewis: What you point out is true. I might add that various eucalyptus trees also have true bark fibers.

Mr. Chesley: That is a good point. I can see that my company won't be asking me to produce bark fibers from our species at Crossett.

Emanual Fritz (University of California): Bark is as much a part of the tree as is wood, and like the wood it must be grown. Its properties, however, are generally such that it has little utilitarian value. A few trees do produce barks valuable for tannin, cork, medicinal bases, and insulation, but, mostly, the bark is a nuisance to the lumber industry.

Since bark adds materially to the cost of "waste" disposal it is only natural that the operator should speculate on its possible conversion from a loss to a profit. Particularly is this true when the volume of the bark looms large. Such is the case with the bark of the Pacific Coast redwood *(Sequoia sempervirens)*.

On individual large old trees redwood bark varies from 3 to 5 inches in thickness to occasionally 12 inches. Such thick bark occurs only in the lower or butt portion of the tree. Upwards from the butt it becomes thinner rapidly. Acre-wise the bulk of the bark is large, varying from 10 to more than 20 cords per acre.

To the redwood lumberman, the bark of redwood causes considerable concern. It is not only thick but also dense, tough and fibrous. A hundred years of sawmill experience has proven that the bark must be removed prior to sawing or else the head saw will not operate well and the lumber will lack uniform thickness. Traditionally the bark was removed in the woods where the tree fell. In recent years a good start has been made toward removing it to a central point, such as a transfer or reloading point in the woods, or at a special landing at the manufacturing plant. There are definite advantages to centralized peeling, such as protection for the logs against bruising during yarding and against damage by an accidental fire, protection against surface checking when logs must be left in the woods several months, lowered cost of peeling, and a reduced fire hazard. Currently it costs upward of $1.00 per M feet, log scale, for direct labor for peeling; indirect costs raise the total close to $2.00 per M. Even if unpeeled logs could be sawed satisfactorily the bark still would pose a problem. All the way from the woods loading point to the sawmill deck part of it tears off and "messes up" the decks. The logger and sawmill man classify the bark problem as their "number one headache."

Not only lumber operators but others have been intrigued by the fibrous character of the bark and its possible utility. Prior to 1920, U. S. McMillan devised a machine for shredding bark strips and slabs and sold the fiber to manufacturers of roofing felts and building

papers. Shortly thereafter, C. H. Brown of Eureka, California established a plant for producing shredded bark for the same purpose and for insulation. Much later John Alexander investigated the use possibilities, set up a plant in Santa Cruz, and promoted the fiber for insulation, a soil amendment, a garden mulch and for various medicinals. But it was The Pacific Lumber Co., of Scotia, California that investigated the bark in a complete and systematic way, inaugurated scientific studies and set up a substantial plant. Its studies began in 1928, and in 1930 it opened its large peeling, shredding, refining and baling plant. Currently there are four shredding plants, but only that of The Pacific Lumber Co. is in steady operation. The scientific investigations were made for the company by the Institute of Paper Chemistry under a long range program of fundamental research directed by Dr. Harry F. Lewis.

The establishment of the "P. L." bark department brought about a marked change in the woods and in the yield of lumber from the logs. The company used to peel in the woods, then it fired the entire peeled timber area to dispose of the debris. After the burning, the trunks were bucked into log lengths, yarded out and transported to the mill. Many of the logs were charred but at that time sapwood was not highly regarded. Now the logs are yarded "with the bark on" and are peeled at the plant. The logs now are bright and clean and the sawyer has a much better opportunity to get the full value out of them.

Any plan to utilize bark must be predicated on volume production of a product that is unique and not readily replaced by a substitute. In this respect the utilization of redwood bark meets its most difficult obstacle. Volume production itself offers no difficulty, but so far, the products that can be made from the bark are either not required in large volume or they must compete with products made for the same purposes from even cheaper raw materials. Shredded redwood bark makes an excellent thermal insulating material. It has found wide acceptance in the low-temperature insulating market, such as cold storage plants, ice plants, and food lockers. These are markets, however, that are served by competing products, thus restricting the volume of bark fiber that can be sold. Dr. Lewis and The Pacific Lumber Co. deserve great credit for their persistent search for possible outlets for redwood bark products. Dr. Lewis, and the company's research director have assiduously gone deeply into the secrets of the anatomical, physical, and chemical characteristics of redwood bark. Dr. Lewis and his staff have enriched the literature with the results of their scientific investigations. The Company's research department constantly investigates every suggestion or idea directed toward diversified and broader uses. Here we have a distinguished example of coordinated business courage, marketing imagination, and scientific investigation converging on a problem of converting a so-called waste material into a merchantable useful product. For 20 years "P. L." has carried on research in the field without let-up. It must be remembered that the nature of the raw material circumscribes the activities of the producer and the scientist. They cannot select the raw material for the manufacture of a product they would wish to make but must find a salable product to make from the raw material they have. So far, insulation provides the major market, but the risk of losing this outlet to another new and cheaper insulation constantly faces the producer as it does in many other lines of business. Yet, the studies continue—for better insulation, for textile uses, chemicals, plastics, hardboards, and a long list of others.

The writer of these comments has probably been diverted too much from his assignment to discuss Dr. Lewis' paper. However, this example of a search for a way of putting a heretofore useless material to a useful purpose against great odds is so noteworthy as to warrant the space to comment upon it.

Dr. Lewis' paper adequately covers the physical, anatomical, and chemical aspects of redwood bark. The writer can make only one addition: the bark powder is made up not only of broken fibers, parenchyma cells and dry extraneous substances but also of the powdery residue left by a type of powder post beetle that infests some of the older and thicker bark and that of a "dry rot" type of fungus. Both

are, as yet, unclassified. The writer has found the larva of the insect but has been unable to rear an adult for classification purposes. Tentatively it is believed to be a member of the insect family *Ptinidae:* The dry rot is very likely *Poria sequoiae,* the same fungus which attacks redwood heartwood. The cubical decay bodies in the bark are independent of any connection with the similar bodies in the heartwood. So far, no fruiting bodies have been found on the infected bark and definite classification cannot therefore be made.

Utilization of Waste Sulphite Liquor in Concrete

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Calcium lignosulphonate derived from waste sulphite liqour is a specific dispersing agent for cement. Studies have been made of various physical-chemical properties of this compound in view of the influences these might have on cement dispersion. Purity is of importance as the sugar content of normal liquor adversely affects cement hydration. An almost ideal composition is secured in the fermentation process for the production of alcohol from waste sulphite liquor. Data are presented to show the improvements in such concrete properties as workability, strength, watertightness, and durability through the use of calcium lignosulphonate.

Introduction

THERE is little need to point out the desirability of finding means for utilizing waste sulphite liquor. A great deal of work has been done on this subject and many different applications of the solids in the liquor, either in their original form or in a modified form, have been developed. These include such applications[1] as the use of the solids as fuel, use in plastics, production of vanillin, for core binders in foundries, in tanning, as adhesives, as fertilizers, and for road treatment. While many of these applications have been more or less successful, they have suffered from the disadvantages either that the processing required before the material could be utilized was as costly or more costly than the value of the material, in many cases, or that only limited quantities of waste sulphite liquor, compared with the available supply, could be used in any of these applications, or in fact all of them together. Utilization of waste sulphite liquor as a dispersing agent for cement in portland cement concrete is another outlet that will consume substantial quantities but can never be expected to take anything like the total output of waste sulphite liquor.

Dispersing agents have long been known and widely utilized in a variety of industries. Dispersing agents are specific in their action and those applicable to one solid-liquid system may or may not be applicable to any other. As far as portland cement is concerned the problem is complicated by the necessity that any dispersing agent to be used with it must not interfere with the hydration reactions of the cement. Until recent years no dispersing agents have been known which were applicable to the deflocculation of cement and, in fact, the benefits to be derived by dispersing the cement had not been recognized. The active component of waste sulphite liquor, calcium lignosulphonate, either as contained in the unmodified waste sulphite liquor or more or less purified has been employed to a limited extent as a deflocculating or dispersing agent for clay slips, dyes, and possibly in certain other applications. It was found that calcium lignosulphonate is a specific dispersing agent for a suspension of portland cement in water.

Nature of Calcium Lignosulphonate From Waste Sulphite Liquor

Our work has not been directed primarily at a solution of the problem of the chemical constitution of calcium lignosulphonate, which has been extensively studied by others and still remains not fully understood. It has rather taken the line of studying the physical-chemical and colloidal properties of this compound that might be expected to be related to its behavior as a dispersing agent for cement.

It is inherent in the very nature of the process that produces waste sulphite liquor that the composition of the calcium lignosulphonate itself varies and that the solids in the liquor are composed not only of calcium lignosulphonate but also of various impurities. While there is a general similarity in the pulping processes that produce waste sulphite liquor, there are differences in the conditions of cooking and differences in the original woods that lead to variations in the final product. Added to this are the changes in the waste sulphite liquor, which may be effected by processes through

[1] Raff, R. A. V. *Lignins—Their Nature and Applications*. Canadian Chemistry and Process Industries. (January 1949).

which it goes after cooking, for one purpose or another. There are, for instance, the fermentation processes used to produce alcohol or yeasts, and chemical treatments applied deliberately to separate out the lignosulphonate compounds in purified forms.

It would be expected that dispersion would necessarily be linked to the adsorption of the dispersing agent by the solid particles to be dispersed and also to the ionization characteristics of the adsorbed compounds. The degree of adsorption would in turn be related to the molecular weight of the dispersing agent, as well as its chemical characteristics. The ionization of the dispersing agent would be influenced by the degree of sulphonation, the number of other ionizable groups in the molecule, and the dissociation characteristics of the ionizing groups.

Calcium lignosulphonate derived from waste sulphite liquor is polydisperse and fractions with average molecular weights as low as 400 and as high as 18,000 have been separated. From some sources it is much less polydisperse than from others. On certain liquors an average molecular weight of about 6,000 has been found, but it by no means follows that other liquors would have the same molecular weight. A considerable amount of work[2] has been done to study the molecular weight of calcium lignosulphonate and it has been found possible, by various means, to produce a material having almost any desired average molecular weight over a considerable range. This can be accomplished by separating different molecular weight fractions of the starting material, for example, by dialysis or by various processes of polymerization or depolymerization. It would be anticipated that the molecular weight would affect the degree of adsorption, and determinations of adsorption isotherms of different molecular weight fractions show that this is the case. As illustrated in Fig. 1, the degree of adsorption increases markedly with increasing molecular weight.

Samples of waste sulphite liquor from different sources and even different molecular weight fractions of calcium lignosulphonate

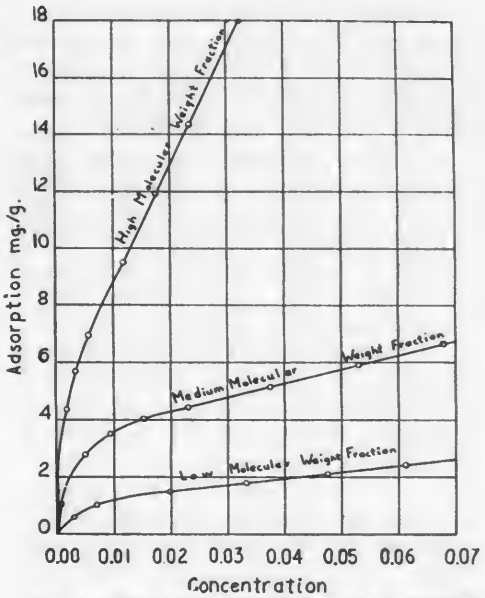


Fig. 1.—The relationship of degree of adsorption and molecular weight of calcium lignosulphonate fractions.

from the same source show differences in degree of sulphonation and also in the hydrogen ion to sulphur ratio. It appeared theoretically that the degree of sulphonation, assuming equal adsorption, should determine the degree of dispersion of the cement. This did not appear to be the case, but another variable, the hydrogen ion-to-sulphur ratio, appeared to be of greater significance. Owing to the complexity of the problem, it was not possible to determine just what this relation is, although one undoubtedly exists.

In the course of the study of the physical chemical characteristics of calcium lignosulphonate, conductometric titrations were used in an attempt to determine the degree of sulphonation and splitting of the lignosulphonate molecules. This method of titration disclosed three points of inflection in the titration curve corresponding to three different acid groups. One of these groups, the first, is obviously the sulphonic acid group. Another, as suggested by a number of investigators in this field, is probably a phenolic group.[3] The third, which has

[2] Ernsberger and France. *Some Physical and Chemical Properties of Weight-Fractionated Lignosulphonic Acid, Including the Dissociation of Lignosulphonates.* Jour. of Phys. and Coll. Chem., 52: 1. (January 1948).

[3] Peniston and McCarthy. *Liberation of Phenolic Hydroxyl Groups by the Alkaline Cleavage of Lignin Sulphonic Acids.* Jour. Amer. Chem. Soc. 70: 1329 (1948).

been largely overlooked by previous investigators, may be a carboxyl group, but this is by no means certain. Obviously, the ionization of these active groups will affect the dispersing action of the calcium lignosulphonate.

The degree of dissociation of the calcium lignosulphonate should affect the degree of dispersion for a given quantity of dispersing agent adsorbed. Studies of the dissociation[2] of various salts of lignosulphonic acid, including the calcium salt, showed a rather peculiar behavior, in that in contrast to a high degree of dissociation for the acid, the calcium salt has a very iow degree of dissociation. This explains the positive adsorption of the lignosulphonate ion by portland cement as due to the affinity of lignosulphonate ions for the cations on the surface of the cement particles. This is confirmed by the almost negligible adsorption of lignosulphonate ions by such absorbents as silica; whereas such materials as limestone absorb them in a manner similar to cement.

The problem is further complicated by the influence of the impurities associated with the calcium lignosulphonate in waste sulphite liquor. Particularly important among these are the sugars. In the neutralization of the sulphite liquor with lime, calcium salts are also obviously produced. In the studies of molecular weight, dissociation constants, and similar physical chemical properties, these impurities have been substantially removed, but they must be taken into consideration as far as the practical aspects of cement dispersion are concerned. It appears that the calcium salts in the product derived from unmodified waste sulphite liquor are not especially harmful, but the sugars adversely affect the cement reactions. These conclusions are reached by physical methods of test rather than by colloidal investigations. On the basis of these observations use of waste sulphite liquor from which the fermentable sugars have been removed in the alcohol process has been adopted, with superior results, to replace the unpurified liquor formerly used.

From the work that has been done on the colloidal characteristic of calcium lignosulphonate some knowledge of its nature has been gained, but comparatively little of value in relation to cement dispersion has so far been derived. It has certainly been proved that removal of the carbohydrate impurities, particularly the sugars, is beneficial. While it seems probable that increase in molecular weight will improve the surface active characteristics of the compound, this conclusion is complicated by the fact that in these investigations the carbohydrate impurities were removed simultaneously with separation of higher molecular weight material by dialysis. There has been some indication that a change in the hydrogen ion-to-sulphur ratio will affect the cement dispersion, but this has been by no means definitely established. While the work done up to this time indicates that the degree of sulphonation of the lignin molecule plays a part, it has not yet been possible to establish what this is. The most practical result of these investigations has been the adoption of a purer calcium lignosulphonate. Even if it could be shown that changes in molecular weight, degree of sulphonation, or other characteristics of the lignosulphonate molecule would be desirable, there would still remain the problem of producing such a modified material economically.

Cement Dispersion

The action of a cement dispersing agent on portland cement in water is similar in its effect to the action of any dispersing agent in a solid-liquid system. The dispersing agent is adsorbed on the cement particles, which thereby acquire like electrostatic charges.[4] The cement particles repel each other and are therefore dispersed instead of flocculated, as they would normally be. The adsorption of calcium lignosulphonate by portland cement is illustrated in Table 1. If a suspension of portland cement in the water is subjected to a surface area determination in a turbidimeter the increase in surface area so found illustrates the degree of dispersion of the cement. Some data of this nature are shown in Table 2. That the cement particles are dispersed by the mutual repulsion of electrical fields around the particles is demonstrated by observation of their electrophoretic migration.[4] Cement particles suspended in distilled water show no tendency to migrate toward either electrode but agglomerate and settle out rap-

[4] Ernsberger and France. *Portland Cement Dispersion by Adsorption of Calcium Lignosulphonate.* Ind. and Engrg. Chem., Vol. 37. (June 1945).

TABLE 1.—PORTLAND CEMENT-CALCIUM LIGNOSULPHONATE ADSORPTION DATA

1.5 percent calcium lignosulphonate	Calcium Lignosulphonate Equilibrium Soln.				Lignosulphonate Adsorption
	Optical Density	Concn.	Concn. obtained graphically	Initial concn.	
Ml.		Percent	Percent	Percent	G./10 g. Cement
0	0.000	0.0000	0.000	0.000	0.000
1	.008	.0022	.001	.010	.013
2	.012	.0033	.003	.020	.025
3	.022	.0061	.007	.030	.035
4	.046	.0128	.013	.040	.041
6	.088	.0247	.025	.060	.053
8	.133	.0373	.037	.080	.064
10	.178	.0499	.051	.100	.073
12	.237	.0662	.066	.120	.081
14	.292	.0817	.081	.140	.088

TABLE 2.—SPECIFIC SURFACE OF PORTLAND CEMENT SUSPENDED IN WATER, WITH AND WITHOUT CALCIUM LIGNOSULPHONATE

Calcium Lignosulphonate Adsorbed	Av. I_{∞}	Av. 2 Log I_{∞}	Av. Transmittancy Constant (1 G. Basis)	Av. Sp. Surface	Apparent Increase in Surface Dispersed over Undispersed
G./100 g. cement[1]	Micro-amp.			Sq.cm./G[2]	Percent
Type I Cement: 90 percent Passing 325-Mesh Sieve; Sp. Surface in Kerosene, 1690 Sq.cm./g.					
None	26.8	0.572	603	1150	--
0.2	24.5	.611	740	(1505)	31
.3	23.2	.635	743	1570	37
.4	21.3	.672	751	(1685)	47
.5	20.7	.684	748	1705	48
Type III Cement: 100 percent Passing 325-Mesh Sieve; Sp. Surface in Kerosene, 2590 Sq.cm./g.					
None	12.5	.903	605	1820	--
.2	11.0	.959	720	(2300)	26
.3	10.1	.996	723	2400	32
.4	8.6	1.065	723	2575	41
.5	8.2	1.086	727	2630	44

[1]Approximate values obtained from adsorption equilibrium data by calculating the total amount of calcium lignosulphonate needed, for the system used, to satisfy the amount adsorbed per 100 grams of cement plus the amount required for equilibrium.
[2]Calculated from individual transmittancy constant; each value is the average of two or more determinations, except those in parenthesis which are single tests.

idly. On the other hand, when suspended in a calcium lignosulphonate solution migration toward the anode is readily observable.

Calcium lignosulphonate is not the only surface-active material that will disperse portland cement. One reason for using calcium lignosulphonate derived from waste sulphite liquor for this purpose is, of course, low cost. Another, and perhaps more important reason, is that the mere dispersion of the cement is not enough. The dispersing agent must not interfere with the hydration reactions of the cement, which are both complex and very sensitive. A study by means of photomicrographs of the hydration reactions of portland cement and the pure portland cement compounds in distilled water and in water containing dissolved calcium lignosulphonate shows that there are differences in the rate of reaction and in some cases in the nature of the hydration reactions. At low concentrations, however, calcium lignosulphonate does not adversely affect the hydration reactions but might be expected to have a beneficial effect due to the higher degree of dispersion and therefore greater surface area in contact with the water. In higher concentrations the calcium lignosulphonate evidently acts as a protective colloid, which retards hydration. The behavior of the calcium lignosulphonate with cement is further complicated if impurities are present. Almost any soluble compound will either accelerate or retard the hydration of cement. Sugar is well known as having a particularly marked retarding effect, and any sugar present as an impurity in the calcium lignosulphonate will have a retarding effect. It is therefore necessary to use a reasonably pure calcium lignosulphonate and to use it in such proportions that maximum dispersion is secured without introducing the retarding effect of a protective colloid. Investigation has shown that proportions between about 0.15 and 0.30 percent of the weight of the cement accomplish this objective. The figures are given as percentages of the weight of the cement, as this is customary practice in the concrete field, but actu-

ally the important factor is not the relation between the quantities of cement and lignosulphonate but the concentration of the solution of lignosulphonate used in making a workable concrete mix.

Action of Cement Dispersion in Concrete

The action of the cement dispersing agent in portland cement concrete is to deflocculate or disperse the cement particles, or at least to reduce the inter-particle attraction. This has a number of important effects. The reactions of portland cement are surface reactions between the particles of cement and the water, which therefore are functions of the surface area of the cement. For this reason cement manufacturers in recent years have consistently increased the fineness of grinding of cement clinker. Unfortunately, the full surface area produced by finer grinding is not effective due to the flocculated condition of the cement in its normal state in the mix. Actually, this tendency toward agglomeration increases with increasing fineness so that the beneficial effects of fine grinding are in some measure offset by this flocculation. By dispersing the cement particles the effective surface area of the cement in the mix is increased.

Another effect of dispersing the cement particles is that water trapped within the particle clumps in the flocculated condition is released to become part of the liquid phase of the concrete. This combined with the more ready movement of the smaller particles, contrasted with clumps of particles, past each other increases the fluidity of the mix with a given water content. What is important is the converse of this, that by dispersion of the cement the water required for a concrete of a given consistency is decreased.

A third fundamental effect of dispersion of the cement with calcium lignosulphonate is that a small amount of air, in the form of microscopic bubbles, is entrapped in the concrete. While there are other means of accomplishing this purpose, the entrainment of air, as this phenomenon is known in concrete technology, is most advantageously accomplished by dispersion. The beneficial effects of air entrainment will be briefly pointed out later.

Effects on Concrete Properties

Since the properties of concrete for given aggregates are primarily dependent on the amount and quality of the cement paste, any influence which alters the nature of this paste will inevitably influence the properties of the mix. Two phases in concrete making should be differentiated. These are the first phase, when the concrete is plastic and ability to place the concrete is of primary importance, and the second phase, after the concrete has hardened and cured when certain other properties are of most significance.

Unless concrete is workable during the plastic stage it is impossible to produce a sound structure, regardless of any other properties of the mix. This property of workability may be considered as made up of two components: mobility or ease of flow, and cohesiveness, which includes resistance to segregation.

Dispersion of the cement particles increases mobility in the manner previously described (Table 3).

TABLE 3.—INCREASE IN MOBILITY

Mix	Water–Cement Ratio	Slump
	Gal. per sack	In.
Untreated	6½	1
Dispersed cement	6½	5

Dispersion also increases the cohesiveness of the mix, partly due to the increased surface area of the cement and partly due to the entrainment of a small amount of air. The mix, while still flowing readily, becomes more "fatty" or "buttery". As a consequence, with a mix that can be as easily or more easily placed in the forms, the tendency of the components of the concrete toward segregation is reduced. Gross defects in the concrete, such as honeycombing and sand streaking, are thereby more or less prevented.

A particular aspect of the increased cohesiveness of the mix secured by dispersion is the reduced tendency toward bleeding (Table 4).

TABLE 4.—REDUCTION IN BLEEDING

(Concrete mix = 6.0 sacks per cu. yd.)

Addition	Bleeding	
	Cement I	Cement II
	Percent	Percent
None	100	100
Dispersing Agent	25	20

Bleeding is essentially segregation of the water in the mix in an upward direction. This phenomenon is also commonly called water gain. Bleeding is an highly undesirable phenomenon, for two reasons. In its upward movement through the mix the water tends to collect under the larger pieces of aggregate, forming pockets on the under side, so that the aggregate is not well bonded to the cement paste. These pockets constitute points of weakness and of attack by destructive agencies and also diminish the strength of the concrete. The second effect of bleeding is to bring a layer of fine material to the top surface of the concrete with a very high water content, commonly known as laitance. Due to the high water content this layer shrinks excessively and has very low strength.

In the hardened state the properties of concrete that are significantly affected by the dispersion of the cement are strength, volume change, permeability, and durability. The strength, as shown by Duff Abrams,[5] is directly related to the ratio between the water and the cement in the mix. Reduction of the water for a mix of given workability through dispersion therefore increases strength (Table 5). Volume change, particularly shrinkage, is governed by the volume of the cement paste, that is the volume of the cement plus the volume of the water in the mix, and for a given mix is reduced by dispersion, again through the reduced water requirement for a given consistency.[6] A further aspect of this property is that for a given strength the cement content of the mix can also be reduced, further decreasing volume change. Permeability is directly related to the total water content per unit volume of the concrete mix, because penetration of liquids through the concrete is dependent on formation of an interconnecting system of capillaries by the water that does not combine with the cement as it evaporates from the concrete after it has hardened. Again, the reduction in water for a given consistency by dispersion of the cement reduces permeability (Fig. 2.).

TABLE 5.—COMPRESSIVE STRENGTH

Cement Content Lb. per Cu. Yd.	Compressive Strength 28 Days	
	No Addition Lb. per Sq. In.	Dispersing Agent Lb. per Sq. In.
300	-----	1, 840
375	1, 500	2, 575
450	2, 150	3, 800
525	3, 560	4, 600
600	4, 350	-----

[5] Abrams, D. A. *Design of Concrete Mixtures—Structural Materials Research Laboratory.* Lewis Inst. Bulletin No. 1. (1918).

[6] Inge Lyse. ASTM Proc. 25:398 (1935).

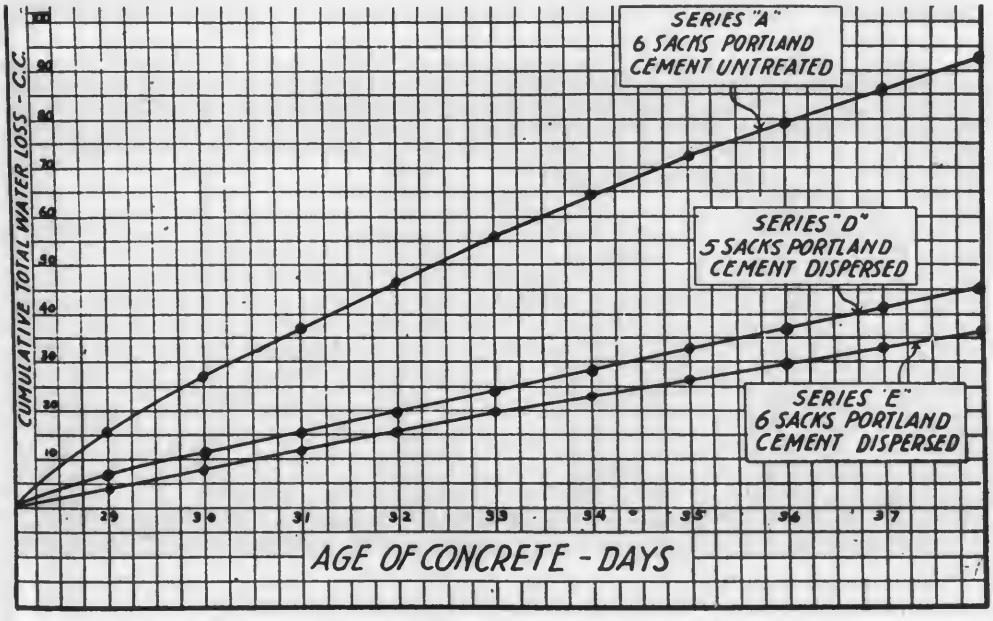


Fig. 2.—Concrete permeability with and without cement dispersion.

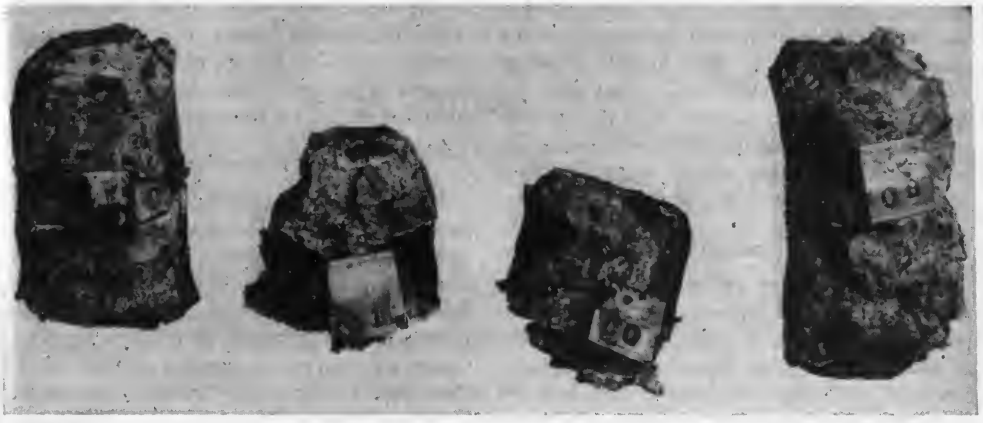
Finally, durability may be considered. In relation to concrete this is usually taken to mean the resistance of the concrete to weathering. The disintegrating influences of weathering are primarily two: freezing and thawing, and attack by corrosive solutions. Resistance of concrete to freezing and thawing is greatly enhanced by the entrainment of a suitable amount of air, which can be accomplished through dispersion of the cement with calcium lignosulphonate (Fig. 3). Improved resistance to corrosive solutions is secured through reduction in permeability of the concrete which, as has been noted above, is secured by cement dispersion (Fig. 4).

One particular problem arises in connection with construction of large concrete masses and, in fact, plays some part even in relatively thinner members. This is the effect of the heat of hydration of cement on volume change. Where large masses of concrete are placed the exothermic hydration reaction of the cement will raise the temperature of the mass considerably above that of the surrounding atmosphere, especially as the concrete is a fairly good insulator. This rise in temperature obviously causes expansion. Subsequently, the mass will gradually cool to the temperature of the surrounding atmosphere and in so doing will contract. The volume change involved is very

(a)

(b)

Fig. 3.—Effect of dispersion of cement upon resistance of concrete to freezing and thawing. (a) Untreated concrete—150 cycles of freezing and thawing. Loss in weight—73%. (b) Dispersed cement, same design and consistency—150 cycles of freezing and thawing. Loss in weight—10%.



(a)

(b)

Fig. 4.—Effect of dispersion of cement upon resistance of concrete to corrosive solutions. (a) Untreated concrete—2 years in 8% magnesium sulphate. (b) Dispersed cement—same design and consistency—2 years in 8% magnesium sulphate.

apt to cause cracking of the mass. It has been shown that calcium lignosulphonate in the concrete does not affect the amount of heat evolved or, to any material extent, the rate of heat evolution.[7] If advantage is taken, however, of the increased strength secured by dispersion of the cement, the amount of cement in the concrete can be reduced, which in turn reduces heat evolution and reduces the danger of cracking through excessive temperature rise.[8]

Another aspect of the use of calcium lignosulphonate in concrete is that of its employment as a grinding aid in the manufacture of cement. In the manufacture of cement the burned clinker is ground to a certain degree of fineness in a ball mill or similar equipment. Addition of a very small percentage of purified calcium lignosulphonate, usually combined with certain other reagents, will increase the efficiency of grinding of the clinker, that is, will grind to a given surface area with a reduced power imput or, what is the same thing, give a higher output from a given mill. The incorporation of the calcium lignosulphonate in the cement in this manner also, in some

[7] Forbrich, L. R. *The Effect of Various Reagents on the Heat Liberation Characteristics of Portland Cement.* Jour. Amer. Conc. Inst. 12. (Nov. 1940).

[8] Forbrich, L. R. *Temperature Effects Near Concrete Surfaces as Affected by Heat Liberation of Cement.* Jour. Amer. Conc. Inst. 13:1. (Sep. 1941).

measure, produces the beneficial effects of dispersion, but only in a small measure, since the quantities required to give highest grinding efficiency are very much smaller than those required to secure the full effects of cement dispersion. Considerable quantities of calcium lignosulphonate derived from waste sulphite liquor have been used in this manner.

Conclusion

The application of calcium lignosulphonate from waste sulphite liquor to the dispersion of portland cement in concrete mixes constitutes an advance in concrete technology. It produces beneficial effects on the concrete mix, both in its plastic state and after hardening. Furthermore, it makes most economical use of the cement. While the general mechanism of cement dispersion with calcium lignosulphonate has been investigated and is understood, there remain many obscure points with relation to the constitution and characteristics of the lignosulphonate as they affect its performance with cement. The improved grinding of cement clinker effected by the addition of small proportions of calcium lignosulphonate to the mill makes possible in some cases production of cement of a fineness that could not otherwise be produced with the usual equipment, and also contributes to the economy of cement manufacture.

Substantial quantities of waste sulphite liquor have been utilized to produce calcium lignosulphonate for use with portland cement either as a grinding aid or as additions to the concrete mix to secure the benefits of cement dispersion. The quantity of waste liquor so utilized, however, represents only a small fraction of that produced. Only a small proportion of the cement produced has been treated in one way or another with calcium lignosulphonate, but it may be of some interest to consider the potentialities. If the annual production of portland cement in the United States is taken as 200,000,000 barrels it may be seen that to grind all of this cement, using calcium lignosulphonate as a grinding aid at the rate of 0.03 percent of the weight of the cement, would consume considerable amounts. If calcium lignosulphonate were added to all concrete made with 200,000,000 barrels of cement annually, at the rate of 0.2 percent of the weight of the cement to secure cement dispersion, the consumption would be six to seven times as large.

Discussion

Harry F. Lewis (Institute of Paper Chemistry): I would like to support what Mr. Benedict said. But let us call it "spent liquor" instead of the commonly used term "waste liquor". In this industrial material, there are 1,500,000 tons annually of calcium ligno-sulfonate represented or about 4 percent of the spent liquor. The sugars in the liquor could, for instance, be used to grow yeast. We should remember that the lignin in the liquor represents no less than one-quarter of the weight of original wood, and we should really not charge it to the cost of cellulose. Spent liquor can't be given away; it must be sold, and so entered in the accounts.

Dr. Scripture: Naturally, I am in accord with what Dr. Lewis has said. The only comment which I might offer is that although I agree that the term "spent liquor" is preferable to the term "waste liquor", common practice dictates the use of the latter as this term has been in use in the industry for a very long time and is still current. For example, *Outlines of Industrial Chemistry* by Thorp (1919) uses the term "waste sulphite liquor" and such recent publications as *Lignin-Chemistry and Utilization, Conference Report* (1947) also uses the term "sulphite waste liquors".

Frederick H. Vogel (Alabama Polytechnic Institute): I agree with you that it is common practice to use the term "waste liquor" just as it is the practice to refer to edgings, trimmings, slabs and sawdust as "sawmill waste". Eventually, as full utilization of the spent liquor becomes a reality, the old term will fall away without fanfare. Except in our own small group, we encounter difficulty in transferring ideas unless we use the common, accepted terminology, and I doubt that full utilization will be hastened by merely changing a name from "waste liquor" to "spent liquor", however logical the latter may be.

Semichemical Pulping

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A mild chemical treatment of wood chips followed by mechanical refining to complete the fiber separation produces semichemical pulps high in yield and strength. The procedure is adaptable to a wide variety of wood species and wood wastes. The pulp strengths obtained are particularly high for hardwoods.

The influence of the chemical treatment with acid, neutral, and alkaline liquors and bleaching on the yield and properties of semichemical pulp are discussed.

The well-established use of semichemical pulp in the manufacture of corrugating board and other products and the indication in experimental trials of the suitability of semichemical pulps for many other kinds of paper are described.

The high yield of pulp obtained by the semichemical processes and their adaptability to many wood species not now used extensively should serve as incentives for even more extensive commercial applications.

ABOUT 90 percent of the fibrous raw material currently used in the United States for making paper comes from wood. The availability and low cost of wood fiber have made possible a very great expansion in the production and consumption of paper since the early days when the industry depended upon other sources of fiber. Yet even today the efficiency of the recovery of fiber from wood cannot be considered to be high, since about half of the wood is lost in the manufacture of chemical pulp.

It is true, of course, that the mechanical process used in groundwood pulping gives a high pulp recovery from the wood used. Wood pulp was first made by this process, and groundwood pulp is still used in large quantities. The uses that can be made of groundwood pulp, however, are limited by its low strength and low brightness. It was not possible to make the wide variety of strong and white papers from wood pulp until the chemical pulping processes, soda, sulfite, and sulfate, were developed.

It was not until the later development of semichemical pulping at the Forest Products Laboratory,[2] however, that any important compromise was feasible between groundwood pulps on the one hand and the low-yield chemical pulps essentially free of lignin on the other. The properties attainable in semichemical pulp have shown that it is not always necessary to destroy so much wood as previously in the manufacture of pulps having the physical properties necessary for strong papers. Pulps with good felting properties and capable of producing other sheet properties necessary for many uses can be obtained without complete delignification.

Semichemical pulping consists of a mild chemical treatment to remove a part of the lignocellulose fiber-bonding material, followed by mechanical refining to complete the fiber separation. Such a procedure can produce pulps varying in yield from a figure above 90 percent for groundwood to the 50 percent or less obtained in chemical pulping. The yield obtained depends upon the severity of the chemical treatment. Generally, the pulp strength increases quite rapidly as the yield is lowered. Pulps produced from some woods under suitable conditions in yields between 70 and 80 percent have strengths approaching those developed in some fully cooked chemical pulps. In the yield range of about 70 percent to perhaps 85 percent, is found the desirable combinations of a high yield, together with comparatively high strength. Rue and his associates used a neutral sodium sulfite liquor to obtain a high pulp strength and a light color in this relatively high-yield range.

Neutral sulfite semichemical pulp is prepared by heating wood chips in the sodium sulfite liquor at temperatures up to 170° C. for 1 to 3 hours. The cooking liquor contains the amount of sodium sulfite necessary to remove the desired amount of wood substance. About one part of sodium carbonate to four parts of

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] Rue, J. D., Wells, S. D., Rawling, F. G., Staidl, J. A. Paper Trade Jour., Sept. 23, 1926.

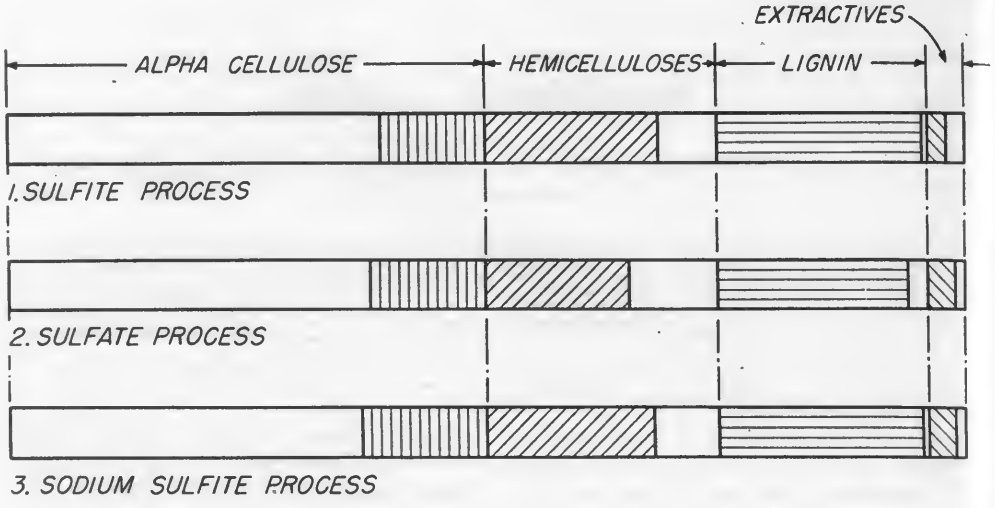

Fig. 1.—Removal of hardwood constituents in chemical pulping.

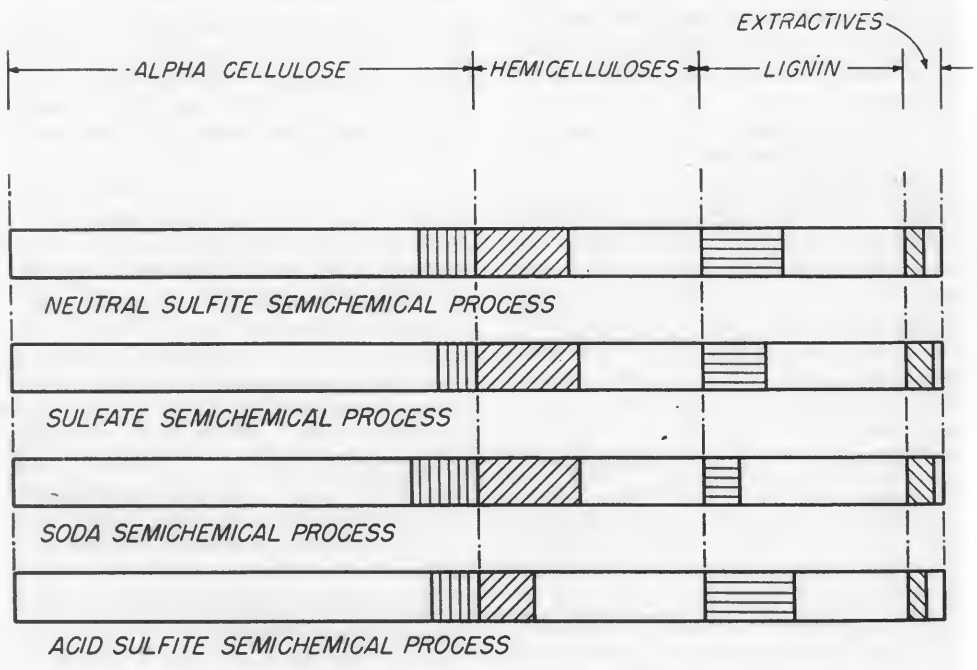

Fig. 2.—Removal of hardwood constituents in semichemical pulping.

sodium sulfite is usually added to maintain a pH neutral enough to prevent excessive corrosion and possible pulp degradation. This treatment removes, principally, up to about half the lignin in the wood and some of the hemicellulose material. The chips are softened so that the fibers can be separated very readily in the mechanical refining.

Somewhat similar results, except for a darker color, can be obtained with conventional sulfate cooking liquor adjusted to the proper concentration of sodium hydroxide and sodium sulfide. One of the advantages of this procedure is that the chemicals in the spent liquor are recoverable by conventional methods. Ordinary acid sulfite liquor can likewise be used. The pulps obtained with this liquor, as with sodium sulfite, are light-colored, but their strength is lower.

Wood Constituents Removed During Pulping

The principal constituents dissolved from the wood during chemical and semichemical pulping of hardwoods are shown in Figs. 1 and 2. The values represented may be considered as fairly typical, but are not constant quantities obtained in all instances, since they vary with the cooking conditions and the wood species. The chemical pulps, acid sulfite, sulfate, and sodium sulfite, indicated in Fig. 1, were all produced in yields slightly below 50 percent. Except for small residual amounts of lignin remaining in these pulps, which were slightly

Fig. 3.—Spruce groundwood pulp highly magnified.

higher for the sulfate pulp, all the lignin in the wood was removed. Considerable quantities of the hemicellulose constituents were also dissolved, and an appreciable quantity of the alpha cellulose was destroyed. The acid sulfite process removes more of the hemicelluloses and destroys a little less of the alpha cellulose than the alkaline process.

The wood constituents removed in semichemical pulping for each of the conventional-type liquors are shown in Fig. 2. The values in all instances correspond to a pulp yield of 75 percent. At this yield the acid sulfite liquor is shown to have removed more of the lignin and, in contrast to the fully delignified pulps, less of the hemicelluloses than the alkaline or neutral liquors. Also, slightly less of the alpha cellulose was removed. The neutral sodium sulfite liquor also removed a little more of the lignin than did the alkaline liquors. The soda liquor, on the other hand, is shown to have removed less lignin and more cellulose than the others.

Fiber Characteristics

In the preparation of pulp for high-quality papers a complete separation of the fibers is essential. Also, the fibers should be capable of developing a satisfactory fiber-to-fiber bond when the sheet is formed and dried. An indication of the degree to which these requirements are met in semichemical pulp compared with groundwood and sulfite pulps, is illustrated in Figs. 3, 4, and 5.

Fig. 3 is a photomicrograph of groundwood pulp showing a fiber bundle and parts of broken or disintegrated fibers. The average

Fig. 4.—Spruce sulfite pulp highly magnified.

fiber length is considerably less than that of the unbroken wood fibers. The sheet strength is low because of the short fiber length and the high lignin content.

Fig. 4 shows well-separated sulfite-pulp fibers, which upon beating are capable of developing fibrillation and good surface bond strength in the delignified cellulose fibers.

Fig. 5 shows the semichemical pulp fibers also to be well separated without excessive disintegration. As a result of the mechanical refining, some fibrillation indicative of the capability of producing good bond strength is evident. Presumably, enough of the lignin encrustant has been removed to allow cellulose bonds between fibers to become effective.

Physical Properties of Semichemical Pulps

Strength values of neutral sulfite semichemical pulps corresponding to yields between 70 and 81 percent are given for 29 hardwoods and 10 softwoods in Table 1. Of the hardwoods, birch, aspen, cottonwood, and sugarberry developed bursting strengths between 0.80 and more than 0.90 point per pound per ream. In the lowest bursting-strength range, from 0.20 to 0.40 point per pound per ream, are the oaks, bitter pecan, and white ash. The pulps in the highest bursting-strength range are about 75 to 80 percent of the corresponding values for spruce sulfite. The tearing strengths, however, are lower. The strengths of the hardwood semichemical pulps are appreciably

Fig. 5.—Neutral sulfite semichemical pulp highly magnified—50 percent jack pine and 50 percent aspen.

TABLE 1.—STRENGTH PROPERTIES OF NEUTRAL SULFITE SEMICHEMICAL PULPS

Species	Pulp yield	Na_2SO_3 consumed	Pulp strength at 550 cc. S.R.[1]			Pulp lignin content
			Burst[2]	Tear[2]	Double folds	
	Lb. per 100 lb. O.D. wood	Lb. per 100 lb. O.D. wood	Pts. per lb.	Gm. per lb.	No.	Percent
HARDWOODS:						
Paper birch	79	10.2	0.93	0.95	315	13.4
Yellow birch	81	11.7	.87	1.17	131	15.2
Quaking aspen	77	11.8	.93	.86	161	11.6
Black tupelo	80	8.0	.64	1.00	29	18.2
Sweetgum	76	9.1	.62	.88	100	14.8
Blackjack oak	78	12.6	.82	.68	---	----
Overcup oak	74	8.3	.29	.57	2	23.7
Post oak	76	6.4	.24	.53	1	18.9
Chestnut oak	75	9.1	.36	.76	9	14.0
Black willow	79	11.9	.79	1.00	100	14.9
Southern cottonwood	79	12.0	.82	.88	150	14.6
Eastern cottonwood	76	13.8	.84	.79	80	15.1
Sugarberry	75	10.2	.80	.96	135	18.0
Green ash	74	9.2	.43	.70	10	21.8
White ash	77	8.0	.30	.67	11	22.4
American elm	81	9.5	.53	.73	6	20.9
Bitter pecan	80	8.1	.35	.80	5	21.7
Hickory	78	10.6	.50	.74	85	16.0
Sugar maple	80	11.0	.64	.74	30	15.8
Soft maple	76	14.1	.74	.95	95	18.8
American beech	77	9.4	.56	.78	29	14.1
Black cherry	72	11.8	.74	.90	50	12.2
Yellow-poplar	76	11.4	.67	.91	25	11.3
Red alder	80	11.0	[3].48	[3]1.34	---	----
Eucalyptus (*gigantea*)	75	9.0	.46	1.17	7	----
Nire	79	11.5	.46	.63	17	16.4
Ulmo	71	15.6	.43	.78	8	11.0
Colgue	74	12.6	.45	.71	46	13.5
Tepa	81	12.8	.52	.80	52	23.8
SOFTWOODS:						
Jack pine	78	19.0	1.08	.93	405	16.0
White pine	81	15.7	.84	.80	380	22.9
Red pine	79	17.5	.85	.70	400	19.6
Shortleaf pine	78	13.0	.58	1.00	60	20.3
Tamarack	77	17.2	.81	1.20	160	19.0
Douglas-fir (second growth)	80	19.8	.82	1.06	155	18.9
Douglas-fir (old growth)	77	17.4	.64	.95	130	20.1
Western hemlock	85	15.3	.92	1.40	150	----
Western redcedar	73	19.8	1.05	.90	500	----
Black spruce	81	21.8	1.07	.80	---	18.7

[1] Schopper–Riegler.
[2] Ream size—25 x 40–500.
[3] 680 cc. freeness.

higher than those of the sulfite pulps made from the same wood and approach the corresponding values for sulfate pulp from the same wood. For a given yield the lignin content of the pulp varies with the amount of lignin in the wood. A high residual lignin content in a pulp may account in part for its relatively low strengths in some instances.

In general, the strengths of the softwood semichemical pulps are higher than those of the hardwood pulps, but in contrast to hardwoods the softwood semichemical pulps have lower strengths than the more completely delignified chemical pulps. For some softwoods, the strengths of the semichemical pulps approach those of sulfite pulps made from the same species, but they are considerably lower than those of their sulfate pulp.

The color of unbleached neutral sulfite semichemical pulps varies with the color of the wood. Light-colored woods produce pulps only slightly darker than unbleached sulfite pulp. The neutral sulfite semichemical pulps of lighter color can be substituted for unbleached sulfite to a certain extent in some products if their strengths are sufficient.

Semichemical pulps tend to produce hard, brittle sheets having low opacity. Although these properties can be controlled to some extent in refining, for many uses it is desirable to blend them with other pulps to compensate for these characteristics. In refining the pulps it is

necessary to accomplish the separation of the fibers to the degree required for their subsequent use. The reduction of shives is particularly important for high-quality papers and for bleaching. It is unfortunate that in refining the freeness, or drainage rate, and the tearing strength are usually reduced more than is desirable in accomplishing the necessary fiber separation. In order to accomplish fiber separation with the least reduction in tearing strength, cutting effects in refining should be avoided as much as possible. An ideal refining treatment would be one capable of producing fiber separation with as little hydration as possible and of providing a means of controlling hydration to the extent required. Considerable improvement has been made in refining semichemical pulps, and many of the uses of semichemical pulps, both in mill production and experimental trials, mentioned later, would not have been possible with the excessively hydrated and lower-strength pulps originally obtained. More recent improvements in refining methods give some promise of attaining more of these effects.

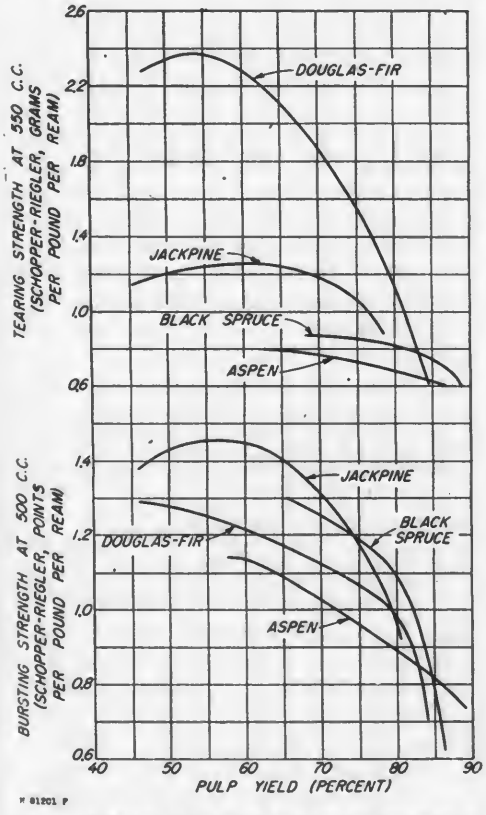

Fig. 6.—Relation of bursting and tearing strengths to yield of neutral sulfite semichemical pulp.

Influence of Yield on Pulp Strength

As mentioned earlier, the yield of pulp decreases and the strength of the pulp improves as the lignin removal progresses with digestion. Fig. 6 shows the variation in bursting and tearing strengths with yield of neutral sulfite semichemical pulp for four species.

It is indicated that the strengths in most instances would reach maximum values at yields between 50 and 60 percent and that they would decrease rapidly at yields greater than 80 percent. Yields greater than 90 percent would probably show bursting-strength values in the low range of 0.10 to 0.20 point per pound per ream, which is below the strength of some groundwood pulps.

Pulp Strengths Resulting From Different Cooking Liquors

In general, the strength of semichemical pulps prepared with acid, neutral, or alkaline cooking liquors have relationships similar to those for the fully delignified pulps prepared with these liquors. The neutral sulfite and the sulfate semichemical pulps have higher strengths than soda or acid sulfite semichemical pulps. With some exceptions the strengths at the higher yields are somewhat higher for the neutral sulfite semichemical pulps than those for the sulfate semichemical pulps.

Fig. 7 gives a comparison of the strengths of these two kinds of semichemical pulps prepared in different yields from jack pine. Although the tearing strength is slightly higher for the sulfate semichemical pulp over the entire yield range, the other strength properties are higher for the neutral sulfite pulp than the sulfate at yields above 65 percent.[8]

Bleaching

Neutral sulfite semichemical pulps from some woods can be bleached to brightness values up to about 75 percent, which is below a high white, in single-stage treatments with

[8] McGovern, J. N., Mackin, G. E., and Chidester, G. H. Fiber Containers, Oct. 1948.

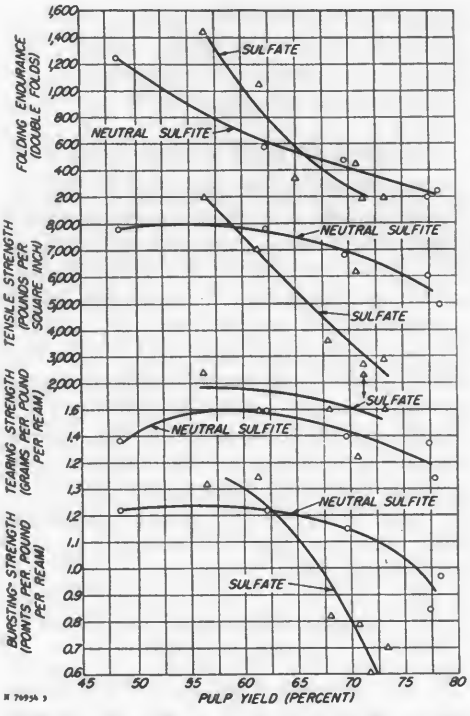
FOLDING ENDURANCE (DOUBLE FOLDS)
TENSILE STRENGTH (POUNDS PER SQUARE INCH)
TEARING STRENGTH (GRAMS PER POUND PER REAM)
BURSTING STRENGTH (POINTS PER POUND PER REAM)
SULFATE
NEUTRAL SULFITE
PULP YIELD (PERCENT)

Fig. 7.—Relation of strength properties of jack pine neutral sulfite and sulfate semichemical pulps to yield of pulp.

either sodium peroxide[4] or hypochlorite.[5] In spite of the high lignin content of the pulp, the reduction in yield on bleaching is small for either procedure, since little lignin is removed under these conditions. A slight improvement in pulp strength results from single-stage bleaching.

Neutral sulfite semichemical pulps can be bleached to brightness values of 80 percent or more, which is within the range of a high white color.[5] This usually requires a multistage treatment with chlorine, caustic soda, and hypochlorite. In such a treatment all of the lignin and some of the cellulose and hemicellulose are removed. Since the lignin content of the unbleached pulp is high, considerably more chlorine (10 to 20 percent of the pulp) is required than is necessary for bleaching chemical pulps. The yield of bleached pulp is 55 to 60 percent of the wood. The removal of lignin in this combination of cooking and bleaching is much more selective than it is in the preparation of bleached chemical pulps with yields below 50 percent, so that the yield of cellulose in the completely delignified semichemical pulp is considerably higher.

It is perhaps equally significant that this delignification and bleaching procedure results in a great improvement in pulp strength. For hardwoods the strength is generally higher than that of pulps prepared by other processes, and for some of them it is equivalent to that of strong softwood sulfites. Because they develop hydration rapidly, they are particularly suitable for glassine paper, but are less suitable for most other papers when used alone. The strengths of pulps made from several hardwoods bleached in this way are given in Table 2.

Sulfate semichemical pulps can be bleached in a similar manner, but they require much more chlorine than the neutral sulfite semichemical pulps because of their higher lignin

[4] Kingsbury, R. M., Simmonds, F. A., Mills, R. T., and Fennell, F. L. Paper Trade Jour., Sept. 12, 1946.

[5] Simmonds, F. A., and Kingsbury, R. M. Paper Trade Jour., Jan. 23, 1947.

TABLE 2.—STRENGTH PROPERTIES OF BLEACHED NEUTRAL SULFITE SEMICHEMICAL PULPS

Species	Yield of bleached pulp	Bleached pulp brightness[1]	Pulp strength at 550 cc. (S.-R.)[1]		
			Burst[2]	Tear[2]	Double folds
	Lb. per 100 lb. O.D. wood	Percent	Pts. per lb.	Gm. per lb.	No.
Quaking aspen	60	77	1.20	1.02	500
Paper birch	57	83	1.18	.90	850
Soft maple	62	66	.93	1.15	280
American beech	59	77	.79	1.13	146
Black tupelo	55	82	1.09	1.35	560
Yellow-poplar	56	82	1.20	1.10	500
Sweetgum	57	81	1.08	1.40	550
Beech, cherry, maple	56	83	.93	.91	220
Eucalyptus	52	85	.86	1.55	300
Douglas-fir	42	84	1.18	2.60	1,000

[1] Schopper–Riegler.
[2] Ream size—25 x 40–500.

content. Acid sulfite semichemical pulps can also be bleached in the same way, but the resulting strengths are lower than the other kinds of semichemical pulps.

Uses of Semichemical Pulp

Unbleached Pulps

Neutral sulfite semichemical pulp was first used commercially for the manufacture of 9-point corrugating board from tannin-extracted chestnut chips. This use has been well-established for many years, and the production of high-quality corrugating board from semichemical pulp from other woods has expanded to approximately half a million tons annually. One of the principal requirements in corrugating board is stiffness in the corrugated sheet. The strength required, however, is comparatively low. A light color is not essential, and shives and specks are not objectionable. The necessary properties can be obtained from most woods. Table 3 lists the properties of experimental corrugating boards made from a number of species and wood wastes.

Semichemical pulp is also used in making some grades of wrapping paper, insulating board, roofing felt, and a few other products.

Experimental linerboards of excellent quality and considerably lighter in color than kraft liners have been made from jack pine semichemical pulp and from mixtures of jack pine and aspen semichemical pulps obtained in yields of 75 to 80 percent.[5] The strength requirements for linerboard are considerably higher than those for corrugating board. The digestion and refining of the pulps have to be carefully controlled so that high strengths are attained at a high freeness. Linerboards of good quality have also been made experimentally at the Forest Products Laboratory from several other species. The physical properties of these linerboards are given in Table 3.

Experimental newsprint papers of good quality have been made by using substantial amounts of hardwood semichemical pulp as a part of the furnish. The comparatively high strength of the hardwood semichemical pulp permits the inclusion of an appreciable proportion of low-strength hardwood groundwood. Good-quality experimental newsprint containing as much as 80 percent birch has been made from a combination of 50 percent birch semichemical pulp, 30 percent birch groundwood, and 20 percent spruce groundwood. Unbleached semichemical pulps of light color can be used to advantage as a partial substitute for unbleached sulfite pulp when it is used in combination with groundwood pulp for other papers and paperboards.

Semichemical pulps from wood waste.—Experimental semichemical pulps have been made from material ordinarily left in the woods after logging and from various forms of mill waste, which may include appreciable quantities of bark and fines. Bark and fines produce dirt and low pulp strength. As much as 20 or 25 percent of such material might be used with wood chips for corrugating board, however, if the species is suitable. Coarse pulps for wallboard, roofing felt, and some other products have even lower strength requirements, and they can easily be met in semichemical pulps made from various forms of waste.

Decayed wood can also be used for making semichemical pulp for uses in which the pulp strength is adequate and the darker color and dirt content are not objectionable. It is indicated that for some kinds of decay, white pocket, for example, there may be little or no loss of pulp strength because of the decay, even though the decay may have progressed far enough to reduce appreciably the specific gravity of the wood.

Bleached Pulps

In experimental trials bleached aspen semichemical pulps have been successfully substituted for bleached softwood sulfite pulp used in combination with aspen groundwood pulp in making paper for machine coating.[6] Satisfactory bulk and opacity were maintained by the groundwood pulp. The relatively high strength of the bleached semichemical pulp was used to advantage in other trials to maintain the sheet strength when a low-strength, free aspen groundwood produced at a low energy consumption was used.[7] Substantial quantities of bleached aspen semichemical pulp are now being used in the manufacture of groundwood

[6] McGovern, J. N. Paper Trade Jour., Nov. 11, 1946.

[7] Mackin, G. E. Forest Products Laboratory Report No. R1709.

TABLE 3.—PROPERTIES OF SEMICHEMICAL CORRUGATING AND LINER BOARDS

Species	Semichemical process	Pulp yield	Properties of paperboards[1]					
			Weight	Caliper	Bursting strength		Tearing strength	Compression resistance
					Mullen	Unit		
CORRUGATING BOARDS:		Lb. per 100 lb. O.D. wood	Lb. per 1,000 sq. ft.	0.001 inch	Pts.	Pts. per lb.	Gm. per lb.	Lb.
Hardwood Pulpwood								
Aspen	Neutral sulfite	78.0	32.6	8.1	101	0.88	0.99	24.2
Do[2]	Sulfate	74.7	25.3	8.9	50	.55	1.01	11.6
Southern cottonwood	Neutral sulfite	79.2	23.7	8.3	50	.50	1.04	----
Do	Sulfate	74.7	39.4	9.0	89	.64	.95	----
Do	Acid sulfite	72.7	86.9	8.5	42	.83	.65	----
Black willow	Neutral sulfite	79.1	40.7	9.6	92	.65	1.04	----
Do	Sulfate	77.5	42.0	9.5	86	.59	1.14	----
Do	Acid sulfite	74.7	82.3	8.8	88	.84	.59	----
Sugarberry	Neutral sulfite	75.0	31.5	8.9	52	.47	1.12	----
Do	Sulfate	74.3	28.1	8.4	44	.44	.89	----
Hickory	Neutral sulfite	78.7	27.3	9.4	45	.47	1.24	18.7
Do	Sulfate	73.9	26.5	8.9	30	.33	1.18	13.8
American elm	Neutral sulfite	81.4	29.7	9.3	38	.86	.81	----
Do	Sulfate	73.0	33.8	9.4	44	.38	1.13	----
Bitter pecan	Neutral sulfite	80.0	30.5	7.9	28	.29	.67	----
Do	Sulfate	73.5	85.4	10.0	53	.48	.92	----
Green ash	Neutral sulfite	74.4	28.2	9.5	14	.15	.52	----
Do	Sulfate	75.3	32.0	9.9	35	.81	.66	----
Sweetgum	Neutral sulfite	79.2	30.2	9.7	51	.49	1.15	----
Chestnut oak	----do----	74.8	25.9	9.6	30	.84	.99	12.0
Do	Sulfate	73.5	26.4	9.3	33	.35	.82	12.5
Overcup oak	Neutral sulfite	75.4	29.8	10.2	80	.29	.52	14.2
Do	Sulfate	68.9	29.9	10.0	36	.35	1.00	12.6
Post oak	Neutral sulfite	76.2	24.1	9.4	17	.21	.69	7.0
Do	Sulfate	69.5	26.1	9.2	26	.27	.70	----
Blackjack oak	Neutral sulfite	71.1	35.9	9.0	58	.47	.87	----
Do	Sulfate	75.7	27.5	9.5	31	.82	.70	----
Hardwood Wastes								
Woodworking wastes[3]	Neutral sulfite	76.4	29.8	9.3	30	.29	.75	9.8
Do	Soda ash	76.7	28.0	9.6	28	.29	.77	10.8
Cull hardwoods[4]	Neutral sulfite	77.9	26.0	9.3	29	.33	.77	9.9
Extracted oak[5]	----do----	72.5	81.2	9.4	38	.35	.72	16.7
Softwood Pulpwood and Wastes								
Young-growth Douglas-fir	Neutral sulfite	84.1	26.5	10.4	50	.56	2.75	10.8
Decayed,[6] old-growth Douglas-fir	----do----	75.4	25.0	8.9	49	.56	1.97	11.1
Do	Sulfate	74.3	26.8	9.4	29	.31	2.23	9.0
Douglas-fir hogged waste	Neutral sulfite	81.5	25.6	11.1	49	.55	2.37	11.9
Western redcedar	----do----	72.7	25.9	9.1	87	.97	1.87	14.2
Western hemlock	----do----	84.7	29.6	11.9	71	.69	2.11	14.8
Commercial Southern Hardwood								
Semichemical	Neutral sulfite	----	26.6	9.8	32	.34	1.33	12.9
LINER BOARDS:								
Hardwood Pulpwood								
Aspen	Neutral sulfite	78.2	57.8	14.7	121	.64	1.33	48.2
Paper birch	----do----	78.6	54.4	15.8	134	.71	1.28	45.7
Eastern hardwoods[7]	----do----	72.0	52.3	15.1	102	.57	1.16	34.9
Eucalyptus (*gigantea*)	----do----	70.7	46.4	14.8	111	.69	1.28	37.9
Softwood Pulpwood								
Jack pine	Neutral sulfite	78.0	48.0	15.5	127	.75	2.12	28.8
Do	Sulfate	73.8	43.4	15.4	87	.58	2.61	19.8
Red pine	Neutral sulfite	79.0	50.4	23.4	100	.57	1.50	22.4
White pine	----do----	81.8	50.6	20.1	107	.61	1.55	28.8
Tamarack	----do----	77.0	53.6	17.2	134	.72	1.78	37.5
Western redcedar	----do----	65.0	46.1	14.4	131	.82	1.57	39.1
Western hemlock	----do----	84.7	47.5	16.9	130	.79	2.30	85.0
Second-growth Douglas-fir	----do----	80.3	48.2	16.0	100	.59	2.92	26.1
Sound, old-growth Douglas-fir	----do----	76.6	48.3	19.8	91	.54	2.65	26.7
Do	Sulfate	63.9	47.8	15.6	64	.39	8.16	24.1
Commercial Southern Pine	Sulfate	48	42.9	14.5	110	.73	3.26	27.2

[1] Ream size—25 x 40–500.
[2] Rough wood used.
[3] Mixture of hogged box, furniture, and veneer mill wastes.
[4] Mixture of sugar maple, red maple, yellow birch, and beech.
[5] Predominantly red oaks, chestnut oak excluded.
[6] Firm-rotted wood used.
[7] Mixture of beech, cherry, and maple.
[8] Not semichemical.

book papers that are machine coated for which they replace a part of the softwood sulfite pulp component.

In small-scale paper-machine trials, bleached semichemical pulps from aspen and other hardwoods have been substituted for bleached soft-

wood sulfite pulp in combination with soda pulp in high-quality, carbonate-filled, groundwood-free book papers with good results.

In mill-scale trials[8] bleached aspen semichemical pulp has been used very successfully in making the high-quality glassine paper ordinarily made from Mitscherlich sulfite pulp.

Other trials have indicated that bleached hardwood semichemical pulp can be used advantageously with groundwood pulp in towel papers when employed in amounts up to 35 percent to replace softwood sulfite pulp.

Bond papers having good formation and surface characteristics and satisfactory strength have been made experimentally by using up to 50 percent bleached aspen semichemical pulp to replace bleached softwood sulfite pulp.

General

It is thus apparent that considerable progress is being made in the manufacture and use of both unbleached and bleached semichemical pulp for various commercial papers and boards. Successful experimental trials have indicated their suitability for many other uses. The high yield of pulp obtained by the semichemical processes and the adaptability of these processes to the many wood species that are available but not used extensively today, should serve as incentives for investigations to apply the processes to other woods and to find additional uses.

Discussion

Irving H. Isenberg (Institute of Paper Chemistry): How do the strength properties of unbleached neutral sulfite semichemical pulp compare with the pulps made by the standard chemical process from the same species of wood?

Dr. Chidester: For hardwoods, the strength of the unbleached semichemical pulp is higher than sulfite pulp from the same wood, but slightly lower than the strength of sulfate pulp. For softwoods, the semichemical pulp strengths are lower than sulfite or sulfate pulps.

Dr. Isenberg: How does the time of developing strength in beating of semichemical pulp compare with the rate for kraft and sulfite pulps?

Dr. Chidester: Hardwood semichemical pulps tend to develop strength more rapidly than hardwood kraft or sulfite. Some softwood semichemical pulps develop strength slower.

Dr. Isenberg: Is it not true that the tearing strength is lower in the semichemical paper?

Dr. Chidester: It is true that the tearing strength of semichemical paper tends to be lower than the maximum values developed in sulfate and sulfite pulps. In the lower range of freeness, however, the tearing strength of semichemical pulps is essentially equal to that of sulfite pulps.

Harry F. Lewis (Institute of Paper Chemistry): Do you get tall oil from this process?

Dr. Chidester: We have no data on that.

W. A. Hosmer (Harvard University): How do the costs of the neutral sulfite semichemical process compare with the costs of the chemical process? And what would be the status of stream pollution in the new process?

Dr. Chidester: The cost of semichemical pulp should be considerably lower than that of chemical pulp. If the spent liquor is discarded, its pollution effect would be approximately one-third that of sulfite waste liquor from the same amount of pulp.

Kenneth G. Chesley (Crossett Lumber Company): This might be a good place to point out that kraft liquor is not thrown away and we have a comparatively minor pollution problem. The difference in the mill waste from the two processes under discussion is reflected in the fact that there is less lignin in the spent liquor from the semichemical process than from the sulfite process.

Dr. Chidester: That is correct. Sulfite waste liquor is usually discharged in the mill effluent.

[8] Fries, Karl W. Paper Trade Jour., May 23, 1946.

Dr. Hosmer: Can your spent liquor be recovered economically?

Dr. Chidester: Sodium sulfite semichemical spent liquor can be recovered in a kraft recovery process where the recovered chemicals can be used for making kraft pulp. Although there are several possibilities, no process has operated successfully on a commercial scale to recover the sodium sulfite semichemical spent liquor and reuse it for the same purpose.

F. Bender (Canadian Forest Products Laboratory): Can you give us some examples of specific pulp yields from your process?

Dr. Chidester: Semichemical pulp yields are ordinarily in the range of 70 to 85 percent of the weight of the wood used.

FOREST PRODUCTS RESEARCH SOCIETY

Dry-Formed Boards, Bonded With Resins or Other Materials

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The subject of dry-formed structural boards, i.e. boards that have not been prepared from watery fibre suspensions, has not received much attention so far from research workers. The most important processes are briefly described and the economics of dry-board production are discussed. A few suggestions with regard to future developments are offered.

Introduction

IT IS necessary to define this subject clearly before discussing it. In this paper structural boards only will be considered. These are often referred to as wallboards. Dry-formed boards, in contrast to boards that have been formed from a watery fiber suspension, are boards the raw materials of which have not been suspended in water for the purpose of sheet formation. This definition does not exclude processes in which the binder is added in liquid form, although these processes are not dry in the sense of excluding all moisture. Included also are materials which, owing to their shape and size, are not called boards, but which are, however, closely related to boards so far as manufacture and uses are concerned, e.g. tiles, bricks, and similar products.

Necessity for Further Investigation

The preparation of dry-formed boards has not, so far, been thoroughly investigated on a scientific basis. No studies as to the influence of important variables on the qualities of these boards have been reported. There are countless technical articles and patents dealing with the preparation of boards and other materials from all kinds and forms of wood waste, but nearly all of these contain nothing but prescriptions as to composition, mixing procedure, and pressing.

On the other hand, if one realizes the large quantity of materials available, the need for cheaper building materials and, last but not least, the desirability, if only in the interests of forest conservation, of the fullest economic utilization of wood and wood products, one cannot help feeling that dry-formed boards utilizing wood waste as a base represent a challenge not only to the inventor and industrialist but perhaps even more to the scientist working in related fields.

There are several reasons for the lack of scientific information on this subject: (1) The most important raw material for dry-formed boards from our point of view is sawdust, a material which so far has been considered either as a nuisance or, at best, as a fuel. Neither aspect tended to stimulate research on board production from sawdust. A comparison with fiberboards, the manufacture of which has greatly profited by the application of scientific methods, makes this point clearer. Fiberboards are based on raw materials which are of tremendous importance in other fields, such as paper and textiles. These fields have, for many years, made extensive use of scientific research, and the methods and results of this research work could be applied, at least partially, to the fiberboard field. (2) Another reason for the lack of development is the fact that good resins became available at reasonable prices only within the last few years.

Types of Binders Used

As pointed out in the definition of the subject, dry-formed boards do not rely on fiber adhesion to provide strength and consequently a bonding element has to be added. As this holds in all cases, it is logical to group the existing boards according to the type of binder. The following binder materials have been used or are being used:

(1) Inorganic materials: magnesia cements, silicates, portland cement.

(2) Organic materials: proteinic materials, such as glues, blood (fresh or dried), casein; starchy materials; synthetic resins; lignin, either that derived from pulping processes or native lignin.

As many of the substances in these groups can be, and actually are, combined with others, it is obvious that the number of variations is considerable.

Boards With Inorganic Binders

Magnesium Compounds

These boards have been rather successful in Europe *(1)* where building materials are expensive and where raw materials are less abundant. One of the various products that have proven to be useful is manufactured by a process that consists of soaking pine shavings in a magnesium sulphate solution, dusting with magnesium oxide, and subjecting the mixture to slight pressure in a heating tunnel with a maximum temperature of 350° C. The processing zone is 260 ft. long and the total processing time is 20 minutes. At the end of the heating tunnel is a small cooling tunnel. The slabs, which emerge still steaming, are cut into 2-meter lengths and stacked. The product weighs 25 lb. per cu. ft. and has a thermal conductivity factor of 0.458. Similar boards are produced from excelsior and magnesia binders. As all processes are continuous, rather large production units are required.

Silicates

Although silicates are widely used in the manufacture of corrugated boards and several other paper products, structural boards based on these materials have, so far as is known, not been successful. The main reason may be the fact that silicates are not sufficiently stable as adhesives. Changes in internal structure, such as transition from gels to crystals, can cause sudden break-down of glue-lines, which would be very undesirable in structural materials.

Portland Cement

Portland cement, at a first glance, seems to possess many of the requirements of a binder for converting wood waste into structural materials. It is cheap, available in large quantities and, by itself, strong. The combination with wood, however, is not ideal, as the rigidity of the set cement on the one hand and shrinking and swelling of partly embedded wood particles on the other hand conflict somewhat. Pretreatment of the sawdust reduces the shrinkage and swelling to some extent, but does not eliminate it. Nevertheless, a number of combinations of cement and sawdust or shavings are being produced and can be used for a limited number of purposes, such as interior walls. The hollow spaces of such boards take up considerable amounts of water; consequently the product cannot be used where it is likely to become wet and cold, as a few cycles of freezing and thawing would weaken and finally destroy it.

Organic Materials

Proteinic Binders

Proteins, such as blood, casein, and vegetable proteins, are used extensively for wood gluing, and it is logical to assume that wood waste glued with these materials can be processed into fair boards and tiles. One of the shortcomings of proteins, i.e., the decomposition by micro-organisms, can be dealt with by the addition of fungicides. In the special case of fresh blood an additional difficulty results from the very rapid decomposition of this material unless special precautions are taken.

Starchy Materials

Starchy materials have not been successful in the manufacture of structural materials, as it has been found impractical to waterproof the resulting boards adequately.

Synthetic Resins

Since the prices of urea and phenolic resins have come down considerably during the last 10 years, these materials have entered the field of dry-formed boards on both sides of the Atlantic. The Germans *(2)* made boards from wood waste and comparatively small amounts of phenolic resins. In England *(3)* boards with urea resin binders are in commercial production, and recently such boards are finding increasing favor in Canada and the United States. All these boards are made along similar lines; wood waste and resin are mixed and the mixture is pressed into boards. Most processes are discontinuous, although complicated ma-

chines for continuous production have been built in England *(4)*.

Lignin

The principal difference between the above-mentioned boards and lignin-bonded boards is the fact that lignin is itself a constituent of wood. As there are various types of lignin, it is preferable to speak of such materials as soda-lignin, lignosulphonic acids, etc. Soda-lignins have good flow properties but, in combination with wood waste alone, produce weak boards. Additions of synthetic resins considerably improve the mechanical properties. In Canada *(5)* one company is manufacturing a board in which soda-lignin serves as a bonding agent. Although this board does not strictly belong to the group of wood waste boards, as it is made from lignin-filled paper sheets that have been laminated under heat and pressure, it is mentioned here because the lignin serves as a binder. A related product is made in the United States in which the lignin also serves as a binder *(6)*.

Lignosulphonic acid or calcium lignosulphonate, available in large quantities in sulphite waste liquor, has been claimed to produce serviceable boards in combination with wood waste. It is not known whether the Smith–Othmer process, which describes such a board, is at present in commercial operation *(7)*.

It is impossible to mention all processes for the manufacture of dry-formed boards. The products and procedures mentioned are only examples typical of certain groups. In Table 1 a few products and some of their strength properties are listed. One point that ought to be mentioned especially is that all dry-formed boards have comparatively high densities which make them less suitable for insulating purposes. The strength of most of the listed products, although lower than the figures for good fiberboards, is sufficient for many purposes.

Economic Considerations

In the second part of this paper, a few general remarks on the economic aspects of the whole problem seem to be appropriate. From the standpoint of cost, wood waste, especially sawdust, seems to be an ideal starting material for structural boards. In many locations it has a very low market value and is produced in sufficient quantities to assure a steady supply of raw material. One of the biggest problems in waste utilization, that of collecting the material, is not present in this case. The data of Table 1 show that sawdust boards are sufficiently strong for a number of purposes, such as partitions, ceilings, and core boards. The question naturally arises, therefore, why more of this material is not being produced. The factors that have held back the production of sawdust boards are:

(1) Established methods of fiberboard production are based on highly efficient continuous processes.
(2) Fiberboards are slightly or markedly superior to dry-formed boards.
(3) As their source of strength is the adhesion between fibers, no binders are required.
(4) Fiberboards can be made in a much wider range of densities. The low density field is entirely reserved for them.
(5) The standards for wallboards were drawn up after some of the nationally known products had established a market, consequently the existing standards take no account of dry-formed boards.

Factors in favor of the manufacture of dry-formed boards are:

(1) Dry-formed boards can be made from nonfibrous material, such as sawdust, which, in many locations, is available at very low cost and in large quantities.
(2) The capital investment for a plant of minimum size for economical operation is much smaller than the cost of a fiberboard plant.
(3) Waste utilization becomes feasible and profitable in locations that have not sufficient material for a fiberboard plant.
(4) It is possible to face dry-formed boards with resin impregnated paper in one operation, thus turning out a product with improved appearance and strength.

In spite of the high standards which fiberboards have reached today, present high prices of fibrous raw materials and the need for conservation seem to favor the development of dry-formed boards. It is true that resin prices are high, but resins form only a small percent-

TABLE 1.—RESULTS OBTAINED WITH EXPERIMENTAL BOARDS MADE AT FOREST PRODUCTS LABORATORY, OTTAWA
All boards were tested after having been conditioned at 70° F. and 65 percent relative humidity

Composition of Board	Conditions of Pressing				Properties of Boards			Remarks
	Temp.	Time	Pressure	Moisture content of mixture	Modulus of rupture	Specific gravity	Water absorption[1] after 2 hrs. submersion at 70°F.	
	°C.	Min.	p.s.i.	Percent	p.s.i.		Percent	
Sawdust (softwood) 10% dried blood, 0.5% phenol	185	5	500	15	1,530	0.810	49.8	Blood dissolved in water, to which phenol was added. Mixture of sawdust and blood dried to 15% moisture content.
Sawdust (hardwood) 8% phenolic resin	163	4	440	15	2,307	.878	25.0	Sawdust and liquid resin mixed. Hot pressed at 15% moisture content.
Shavings+Sawdust (softwood) 15% urea-formaldehyde resin	130	5	150	15	433	.39	83.0	Watery resin solution mixed with wood waste. Mixture dried to 15% moisture content.
	130	5	250	15	544	.505	45.0	
Sawdust (hardwood) sulphite waste liquor, oxalic acid	198	8	500	15	3,700	1.32	2.7	300 g. sawdust mixed with 800 ml. sulphite waste liquor. 10 g. oxalic acid dissolved in 200 ml. water added. Mixture dried to 15% moisture content.

[1]Based on oven-dry weight.

age of the dry-formed boards. Estimates of the required investment for machinery of a minimum size plant are not available in the literature. However, a figure of $100,000 to $125,000 should not be too far out of line—the biggest item being a multi-opening hot-press. A small fiberboard mill of conventional design costs considerably more. Whereas a number of sawmills might be prepared to invest $100,000 to $150,000, they are either not in a position or are reluctant to build a fiberboard plant costing several million dollars. These same sawmills might have sufficient raw material for a dry-formed board plant but insufficient for a fiberboard mill; the latter not only requires a larger tonnage per day but utilizes mainly that part of the waste which is fibrous in structure. From the point of view of waste utilization, dry-formed boards can become a very desirable supplement to fiberboards.

Suggestions for Improvements

So far an attempt has been made to describe the existing situations. A few suggestions for possible improvements in dry-board manufacture will now be made. Dry-formed boards are based on rather heterogeneous materials. This makes it impossible to recommend procedures of general application, and the following remarks are made with this fact in mind.

All dry-formed board making is essentially nothing else but gluing. Consequently, requirements for good glue-lines, such as properly chosen pressing time, temperature, and humidity, should be applied. Pressure is a very important factor. It is often applied in such a way that considerable pulsation occurs. With thermo-setting binders especially, this seems to be undesirable and it would seem worth while to investigate the influence of pressure fluctuations on the quality of dry-formed boards. As the main impediment to increased production of dry-formed boards is the high price of binders, development of new low cost binders is essential. Thermo-plastic materials are especially mentioned in this connection, as prices are high. They can be plasticized and their use as binders would produce stronger boards.

Lignin has many good qualities as a binder, but also some weaknesses. A very interesting development on the Pacific Coast makes use of decayed wood, brown rot, which is claimed to be largely lignin, as a binder for a hard board *(8)*. If it proves true that the lignin left behind after a micro-organism has destroyed the cellulose has properties superior to those of chemically prepared lignins, micro-biologists could help in the growing of such organisms on wood waste under controlled conditions. The generally accepted explanation of the development of brown rots is that the cellulose is removed by micro-organisms. It is conceivable that not only can lignin be made available by micro-biological methods, but that part of the wood could be converted to proteinic material by using suitable organisms. The resulting mixture of woody material and proteins could be formed into boards, the protein acting as a binder.

It is obvious that the derivation of the binder from wood waste itself would eliminate the greatest obstacle to a substantial production of dry-formed boards, namely the need for the addition of a binder. Dry-formed boards will not endanger the well-established position of fiberboards, but they can develop into valuable and versatile products and by so doing permit the use of some forest products that are now wasted.

Literature Cited

1. B.I.O.S. report 489, item 22.
2. Holzforschung 1, (1948) p. 21–24.
3. British Plastics, Dec. 1947, p. 539.
4. Modern Plastics, Sept. 1947, p. 89.
5. Paper Trade Journal 122, (14) p. 35–42.
6. Modern Plastics, Sept. 1942, p. 64.
7. Chem. & Eng. News, Oct. 25th, 1945, p. 1887.
8. Wood Products, Feb. 1947, p. 44.

Discussion

R. E. Dodd (Durez Plastics & Chemicals, Inc.): The dry-formed board bonded with phenolic resin as listed in the table of your paper exhibits low strength. Boards made in our laboratory were considerably stronger.

Dr. Bender: The board listed was picked out at random from a great number of experimental boards made some time ago with a straight phenolic resin (alkaline catalyst).

Many presently available resins will produce boards stronger than the one listed.

Mr. Dodd: We know that very satisfactory board material can be made, using a dry mix of Durez powdered resin and waste wood, such as sawdust. A weight of resin equal to between 8 and 10 percent of the weight of the sawdust is sufficient to produce a board that can be readily nailed and sawed and which is strong enough for many purposes. Higher percentages of resin will naturally make a stronger, denser board.

Robert M. Boehm (Masonite Corporation): Which gives the greater strength under similar conditions, dry forming or wet forming?

Dr. Bender: Conditions are not similar, but wet-formed boards are generally stronger than dry-formed boards.

Mr. Boehm: Then, why make the dry-formed board?

Dr. Bender: Dry-formed boards are strong enough for many purposes and their manufacture might be possible for many smaller concerns that do not have sufficient raw materials to supply a wet process, and that are not in a position to finance a fibreboard plant.

Mr. Boehm: There are many disadvantages of the dry-forming process. For instance, the cost of the resin of a dry-formed board with 15 percent binder would constitute 85 percent of the total cost.

Dr. Bender: Dry-formed boards are recommended, not against wet-formed boards, but only as supplements.

Mr. Boehm: There is a common fallacy in connection with dry forming. It is often assumed that this method introduces a considerable saving by avoiding the necessity of drying out the large amounts of water used in wet forming. Actually, practically all of the added water is removed mechanically so that in the final drying step there is little difference in the amount of water to be evaporated, and the advantages secured in using water as a vehicle for the refining, screening and forming operations are secured with little, if any, increase in the heat units required in the final drying.

Armin Elmendorf (Elmendorf Research, Inc.): Several technical problems must be carefully analyzed before the manufacture of dry-formed sawdust boards can be safely compared with the manufacture of boards made by felting fibers from a water suspension. The subject is complex and cost data are not readily available. Here are some of the technical questions that determine whether dry-formed sawdust boards of the same strength, appearance and general stability as the conventional wet-formed boards can compete with the latter:

1. As most sawdust has to be dried and comminuted to uniform size before it is ready for use, means for drying must first be perfected. It is relatively easy to dry a wet lap deposited on a screen or cylinder and much more difficult to dry an equal weight of sawdust.

2. While the fibers of a wet-formed board cost more per ton than sawdust, less fiber is required to obtain the same strength.

3. For wet-formed boards, 3 percent of resin may be used, whereas at least 8 to 10 percent is generally required for the dry-formed boards of the same strength. For a board weighing 1 pound per square foot, the additional resin will cost about $15.00 per M square feet of board and constitutes a liability of the sawdust board. If the fibers cost $30.00 per ton and the graded and comminuted sawdust $10.00, the difference in cost amounts to $20.00 per ton or $10.00 per M square feet of board. This fact is in favor of the sawdust, but when both factors are considered the balance is in favor of the fibers and the wet process.

4. The lower capital investment for manufacturing the sawdust board is in favor of this product, but total manufacturing cost must be considered and it is compounded of raw materials, depreciation and interest on the investment as well as many other items generally grouped under factory overhead, plus labor and supervision. When the low labor cost of the wet-formed board is considered and the high production per dollar of investment, the advantages, if they exist in favor of the dry-formed sawdust board, are not at all obvious.

The total manufacturing cost is made of many items, and accurate cost estimates are not easily made, but a sound and reliable comparison of the ability of the sawdust board to compete with the fiber hardboards makes the acquisition of all data bearing on costs the first and most important job for the consulting engineer making the analysis.

Dr. Bender: Sawdust is by no means an ideal raw material for boards and, wherever wood waste still contains fiber, one should attempt to make use of the fibrous structure of the material. The combination of the fibrous part of the wood waste with the simultaneously available sawdust will, in most cases, be a logical approach.

FOREST PRODUCTS RESEARCH SOCIETY

Notes on Wood, Plywood, and Hardboard

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The natural deficiencies of wood can be materially reduced by the use of plywood, low-density fiberboards, and more recently developed hardboards and related products. By a unique process of breaking and rewelding the basic wood bond, with fibers interlaced in all directions, structural panels are produced which have uniformly distributed properties of strength and dimensional change. Valuable by-products may be obtained for use as binders, resin extenders, and other purposes. Variations in the process make possible several related high-density products.

Introduction

WOOD fills a position of singular eminence in the field of materials of construction. It has attained this position in the face of certain native deficiencies. For example it burns, shrinks and swells, splinters and checks; it is attacked by decay and insects, and its properties vary greatly, not only from species to species, but from tree to tree.

Developments in wood utilization are a tribute to those who have worked with forest products. Developments in impregnants, coatings, and densification[1] have expanded and are continuing to widen the variety of applications to which this versatile product can be turned. Similarly, improvements in the development of structural panels have been far from negligible. It is with the purpose of charting at least part of the progress in the latter field that this paper is submitted.

Fundamentally, the properties of wood originate in the structure and characteristics of the wood fiber itself. For purposes of simplification, it may be likened to a tube made up of windings of cellulose fibers, each having very high tensile strength. These cellulose fibers are sheathed with and cemented together by what is probably the finest organic binder known, lignin. Interspersed in this structure are the hemi-celluloses, the precursors of the wood sugars. Only by degrading and dissolving out the lignin through the action of strong chemicals, can the cellulose fibers be separated from one another.

In natural wood, these fibers are almost all parallel to the trunk of the tree. This directional alignment of the fiber structure is at once a source of advantage and difficulty. It gives high strength parallel to the grain but very low strength perpendicular to the grain.[2] Strength varies considerably between woods of the same species, even from the same locality—a variation which may be as much as 50 percent from the average.[3] In attaining its hygroscopic equilibrium with air at different humidities, wood may swell or shrink 100 times as much across the grain as it does with the grain.[4]

Plywood

Plywood represents a major advance in overcoming these defects of natural wood. To equalize dimensional changes and strength variations in the two surface directions, the plywood laminate is customarily arranged with the grain of adjacent plies at right angles. The increased utility of such construction is well known. Unfortunately, in the construction of plywood, special care must be exercised in the selection of wood, and in the thickness and arrangement of plies, in order to approach the maximum practical values. Equalization of strength at all surface directions is seldom practical and may not be economically justified because of the increase in number of plies required. The natural variability of wood still

[1] A. J. Stamm, Forest Products Lab., Mimeo. R1482, December, 1944.

[2] L. J. Markwardt and T. R. Wilson, U. S. Dept. Agri., Tech. Bull. No. 479, September, 1935.

[3] C. H. Snow, Wood and Other Structural Materials, McGraw-Hill Book Co., New York, 1917.

[4] R. F. Luxford and G. W. Trayer, U. S. Dept. Agri., Wood Handbook, (Rev.) June, 1940.

asserts itself so that shrinkage and expansion of plywood from some species may be approximately five times that of others. Nevertheless, the relative shrinkage of plywood in any direction is normally less than one-tenth of the cross-grain shrinkage of wood.[5]

Low-Density Fiberboards

Another advance in the use of wood for structural panels is the manufacture of low-density fiberboard or wallboard. Wood is separated into coarse fibers by refining and, after various treatments, is formed into sheets, which are consolidated and laminated. The chief advantages accruing from this process are the uniformity of properties in all surface directions and the ability to utilize wood resources unsuitable for the more specialized requirements of plywood. These advantages, however, are accompanied by a basic deficiency. The process has mechanically separated the fibers without reactivation of the lignin and therefore the product depends for its strength on a paper-type bond, which loses much of its strength on wetting. Efforts to overcome this difficulty by impregnation with resins and other materials have improved the situation, but have not succeeded in duplicating the powerful bonding action of lignocellulose in natural wood.

Hardboard Manufacture

A more recent development in the wood utilization industry, which serves as the main topic of this paper, is that of hardboard and related products. Lignocellulose products of this type originated some 25 years ago with the development of the Masonite process. The wide range of applications, enhanced by the variety of materials with specialized properties which may be produced, has marked a significantly expanded utilization of forest products.

While almost any fibrous lignocellulose material may be used, in the normal process the chief raw material consists of hardwood and softwood logs, approximately 5 feet long, and 5 inches or more in diameter. These logs are barked, chipped, and screened, after which they are conveyed to bins for storage prior to defibration by explosion. The guns constitute the heart of the Masonite process. It is here that the wood is hydrolyzed, wherein the hemicellulose is broken down and prepared for removal and the lignin-carbohydrate bond is released. The type of product desired governs the conditions in the gun and the extent to which the reaction is allowed to proceed. In general the treatment consists of direct steam application over a precisely controlled cycle, ending at 1000 psi. and 550° F. The gun charge is then released suddenly, with the result that the hydrolyzed chips are exploded into a brown, fluffy mass of fiber. The most important feature of this fiber is the modified nature of its lignin content. Though still evenly distributed on the fiber, the greater part of the lignin has been freed from its carbohydrate bonds. In its new state, it merely awaits the proper conditions of heat and pressure for the "wood type" bond to be re-established. This bond gives products characterized by high strength both in the wet and dry condition; and, because of the heterogeneous arrangement of fibers, possessing a strength uniformly distributed in all surface directions.

Subsequent to the gun treatment, the fiber is washed for removal of the hemicellulose extractables, which are concentrated and spray dried to form useful by-products. This material is available in two forms—a 55 percent concentrate known as Masonex and a dry powder called Masonoid. It has found particular application as a binder in numerous fields, which, coupled with other uses developed by research, make this product particularly interesting.

After washing, the fiber is refined and screened. At this point, the finer fractions may be separated for drying and bagging as the commercial product Benaloid 1000, which has found particular application as a resin extender and in the foundry field. These fine fibers, however, may be used in other products with the coarser fibers, and are in fact, necessary to the manufacture of certain products.

The wood fibers, in water slurry, are delivered to a modified Fourdrinier-type forming machine, where they are formed into sheets, called wet laps, and are cut to the proper length. In the manufacture of the familiar Masonite Presdwood, this wet lap is delivered immediately, twenty sheets at a time, to multiple-opening hydraulic presses fitted with steam-heated, chrome-finished plates. In the

[5] Forest Products Laboratory, Report No. 1302, December, 1941.

press, each sheet rests on a wire screen which leaves a characteristic impression on the back of the product and allows the escape of moisture and steam. Pressure and heat are applied to produce moisture free panels of the desired thickness and density. In the case of Masonite Standard Presdwood, the specific gravity is approximately 1.00. The hardboard may next be impregnated with liquid resins to enhance its strength, moisture resistance, and hardness. The impregnated panel is "tempered" by curing at high temperatures, after which it is humidified to equilibrium moisture content. The product, known as Masonite Tempered Presdwood, has a specific gravity of about 1.10, a modulus of rupture exceeding 10,000 psi., and a tensile strength of more than 5,000 psi.

In the case of Masonite Duolux, the wet lap is passed through a tunnel dryer at high temperatures, from which it is delivered substantially free of moisture. The dry lap is then conditioned in a controlled humidity atmosphere to a definite moisture content and is placed in multiple-opening hydraulic presses, each sheet between two chrome-finished plates. After application of a controlled cycle of heat and pressure, the panels are discharged at a specific gravity of approximately 1.15. These panels are then tempered and humidified to produce hardboard, smooth on both sides, with a specific gravity of approximately 1.20, a modulus of rupture of 12,000 psi., and a tensile strength approaching 6,000 psi.

Summarizing, by a unique process of breaking and rewelding the basic wood bond, with fibers interlaced in all surface directions, structural panels are produced which have uniformly distributed properties of strength and dimensional change.

The development and manufacture of hardboards is only a part of the contribution made by this industry to increased wood utilization. A variety of products, ranging from low to high specific gravities, are also produced. At the low end of the density scale is Masonite Cellufoam, an insulating material with a specific gravity of approximately 0.02. This product is manufactured by a somewhat different process than that previously described. Cellulose fiber, normally kraft, is disintegrated in water and a foaming agent added. A stable foam, with complete dispersion of fibers, is obtained upon violent agitation with air injection. This foam is formed into a sheet on a modified Fourdrinier machine and is passed through a tunnel dryer. When dry, it exhibits comparatively good resistance to water, and has a thermal conductivity of 0.26 Btu's per hour per square foot per degree Fahrenheit per one-inch thickness.

Modifications

A relative newcomer to the variety of products stemming from the Masonite process is Masonite Leatherwood, a durable hardboard panel with grained surface strikingly like that of a fine leather finish. This panel is finding particular application where durability must be accompanied by a rich, pleasant appearance. The surface is attractive in its natural brown, and can be finished in two-tone colors. The panel is produced by a process similar to that of Masonite Tempered Duolux.

A more familiar product, Masonite Temprtile, is also manufactured by the use of special forming plates in the hydraulic presses. This hard, tile-like, moisture-resistant panel, when properly coated, provides an attractive wall finish, featuring ease of installation and excellent wearing properties.

By modifying the gun treatment to provide a semi-plastic fiber, and incorporating changes in the handling of the formed lap prior to and during pressing, a high density material, Masonite Die Stock is produced. This material is laminated with resins to give 4- by 12-foot panels in thicknesses up to 2 inches, at a specific gravity of 1.4 or about the ultimate density of wood material. This product played an important role in the wartime development and expansion of the aircraft industry. Its hard, smooth, abrasion resistant surface and its durability indicate that this material has a versatility of application which has only been partly explored to date.

A somewhat similar high density product, Masonite Benelex 70, was developed as a high grade electrical insulation for use in panels and mounting surfaces for current carrying equipment. This material has high arc resistance, excellent dielectric properties, and is unaffected by transformer oil. Continuing research has led to distinct improvements in this product, which will soon be commercially available.

In conclusion, we have attempted to explore some of the progressive steps in the modification of wood to enhance its usefulness to man and minimize its drawbacks. Through the development of plywood and more particularly lignocellulose hardboard, dimensional change and non-uniformity of strength properties have been greatly reduced for structural panels. In the latter industry, many new and useful materials have come through the vigorous prosecution of research. Based on the present knowledge of wood and the manipulations to which it can be subjected, it does not seem at all improbable that a continuing active research program will result in even greater expansion of uses for forest products.

Discussion

Armin Elmendorf (Elmendorf Research, Inc.): We will readily grant that the difference in the physical properties of wood in the direction of the grain and across the grain is very great; also that the properties vary considerably from one sawed board to the next. But there are some uses for lumber where the difference in strength in the two directions is a definite asset and where the uniformity of properties of the synthetic board is a liability. In the case of lumber sheathing, the studding provides the strength and stiffness in one direction and the strength with the grain of the sheathing, that is across the studding, is its important strength property.

A synthetic hardboard 1/8-inch thick costs roughly about the same as lumber sheathing 3/4-inch thick, and the modulus of rupture of the lumber is about twice that of the hardboard. As the strength varies as the square of thickness, it may be seen that a piece of lumber used as sheathing supported in cross-bending by studding is about 72 times as strong as the hardboard costing the same.

It will also be borne in mind that the nail holding power of lumber is very much higher than that of synthetic hardboard of the same cost.

Where nail holding power and strength in one direction are important, ordinary lumber therefore has great advantages over the synthetic product.

Mr. Boehm: In general, if the specific gravity of the average construction wood is considered to be about one-half that of pressed boards, for the same weight, the thickness should be doubled, resulting in four times the strength or eight times the stiffness in static bending. In tensile strength, the results would, of course, be proportional to the thickness, assuming approximately the same values for modulus of rupture and modulus of elasticity, which is a fair assumption for tempered Presdwood as compared to the ordinary wood used in construction.

Where high directional strength is desired per unit weight, there is no question but that wood is superior. We would not make fly rods of hardboard. However, considering both products as a structural materials only, I want to stress the large variations in strength in natural wood and the very high safety factors required as compared to hardboards or even to plywoods. Reference to these variations are listed in my paper.

Compreg—Resin-Treated Densified Wood

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The manufacture and properties of compreg are summarized and its properties are compared to those of wood and metal. The present uses for compreg and the properties of this material that make it suitable for a variety of added uses are discussed.

Introduction

COMPREG is a phenol-formaldehyde-impregnated wood-veneer laminate; compressed under high heat and pressure to a density of approximately 1.35, combining the properties of wood and plastics.

It is manufactured commercially by several laminators in the United States to fill the need for a material that is harder and more stable than wood and lighter than metals.

It is used extensively in the metal tooling, aircraft, textile and woodworking industries because of its dimensional stability, strength and permanent beauty which is obtained simply by buffing the machined surfaces.

Compreg is the generic term applied to resin treated, laminated, compressed wood which is marketed under such trade names as Pregwood, Compregnated Wood, Pluswood and Hi-Den.

The term "compreg" should be reserved for woods that are truly treated, and not be given to laminated compressed wood that may have been impregnated by only a very small amount of glue line resin such as "super-pressed plywood" *(7)*. Impreg *(2)* which is resin treated but not compressed, and Staypak *(2)* which is compressed but not treated, are sometimes erroneously confused with Compreg.

The development of compreg has been fostered by two factions, namely those interested in the advancement of wood products and those engaged in the manufacture of laminated plastic products. The object of the former group has been to improve the utility of wood by modifying its properties with emphasis on improving dimensional stability. The plastics industry has recognized wood as a suitable reinforcing medium to augment and broaden a line which included various paper and fabric base laminates. The efforts of such men as Dr. A. J. Stamm and Messrs. Seborg and Millet of the U. S. Forest Products Laboratory in conjunction with industrial laminators, such as Formica and Parkwood, and resin manufacturers such as Bakelite Corporation, are rewarded as compreg gains recognition as a valuable industrial tooling, structural and decorative material.

Commercially, compreg is a relatively new material, harder and more stable than wood and lighter than metal, combining the better qualities of both wood and plastic. Before the war, production was insignificant, although two large electrical manufacturers produced and consumed quantities for insulating parts where tensile strength, rigidity and moisture resistance were of importance. In 1944, approximately 1,000,000 pounds of compreg were manufactured for aircraft propellers alone. In the postwar era, compreg has filled a need for a hard, durable decorative material where ebony, rosewood and teak supplies were limited and used extensively by designers and engineers in the textile, rubber and metal tooling fields.

Although most woods, with the exception of some hard woods such as oak and the heartwoods of a number of softwoods can be impregnated with resin, commercial compreg is mainly processed from yellow birch or hard maple in $\frac{1}{16}$-in., or $\frac{1}{8}$-in. veneers, since these woods yield the best balance of ultimate properties and are readily available.

Resins Used

The resin treatment has a two-fold purpose, first to deposit an inert bulking medium within the cell wall structure of the wood to dimensionally stabilize it, and second, to provide an adhesive to bond the veneers. Many resin forming systems have been tried, but none has been found so effective as a water-soluble phenol-formaldehyde resinoid. The water-soluble res-

inoids are formed from phenol and formaldehyde with only limited polymerization, so the molecules remain small enough to penetrate the cell wall structure readily. Because of the high polarity of these low polymers, the wood is swollen beyond its maximum swelling in water, indicating a selective adsorption of this type of resin within the intimate cell wall structure. Alcohol-soluble phenol-formaldehyde resins which have been slightly polymerized are also used, but since most resins of this type are advanced to larger molecular structure, they do not penetrate the cell wall structure and thus fail to provide the stabilizing effect. Such resins have been used in Europe in making the equivalent of compreg, but they are not used in the United States.

Resorcinol resin can be substituted for phenol resin, but it is considerably more expensive. Its only advantages are that the resin can be set at lower temperatures and, since no acid or alkaline catalyst is needed, it offers the possibility of obtaining a product with somewhat better electrical resistance properties.

Cresols can be substituted for part of the phenol, but because of their lower solubility in water they are less suitable than straight phenol and are more expensive in the United States. Substituting furfural for formaldehyde also reduces the water solubility of the treating system. Furfural-aniline and furfural-alcohol systems have been tried and found to give fairly good dimensional stabilization, but they are difficult to cure completely within the wood. Melamine-formaldehyde resins have not been thoroughly studied as impregnating agents for wood, because their cost is higher than that of phenol resins and there is little likelihood that they would impart superior properties to the wood.

Urea-formaldehyde is the only resin-forming system other than the phenol-formaldehyde system that has received serious consideration for the bulking treatment of wood. Dimethylolurea and urea dissolved in formalin, when buffered at a pH of about 8 and cured within the wood, give about one-half the stabilizing effect of water-soluble phenol-formaldehyde resinoids in the same concentration *(4)*. A 13 percent phenol-resin content of the wood gives it the same dimensional stabilization as a 30 percent urea-resin content. This greater stabilizing effect of phenol resin offsets any price advantage that the urea resin may have. Urea-resin-forming systems are further inferior to phenol systems in plasticizing the wood prior to cure, in preventing springback in compressed wood *(5)* and in ease of their distribution throughout the wood *(6)*. Only a limited amount of urea-resin-treated wood has been made commercially.

Compreg Processing

The impregnation of veneer used for processing a grade of compreg with maximum dimensional stability and moisture resistance is best effected by total immersion. At atmospheric pressures, the immersion time is about 24 hours, depending on the thickness, size and type of wood. Impregnating time can be appreciably reduced by vacuum-pressure treatment in an autoclave. The resin content of the veneer based on the oven dry weight of the untreated wood is controlled at about 30 percent, although higher impact values are obtained at lower resin contents with a proportionate loss in moisture resistance.

After impregnating, the resin is allowed to diffuse and then is dried to a moisture content of from 2 to 5 percent, depending on the thickness to which it is to be laminated. Thick panels require a low moisture content to avoid subsequent checking of the product, while thinner material may be processed with better appearance at the higher moisture content.

The laminating of veneers into compreg panels is effected by curing the stock at 300° F. under pressures of 1000–1500 p.s.i. with a cure time of approximately one hour per inch of stock. The thermosetting resins used necessitate cooling to room temperature under pressure which usually is effected in less time than the cure cycle, depending on the temperature and pressure of the available water supply.

The manufacture of compreg on a commercial basis necessitates the use of a large volume of veneer and resin, and presents many varied problems such as the effect of heart- or sapwood, spring- and summerwood veneer, and aging of resin. Since the dimensional stability of the ultimate product depends on the bulking of the cell wall structure, and the resinoid causes swelling in the immersion stage, strains are obviously set up as the resin flows and

chemically cross links under high pressures and temperatures, and the veneer is exposed to severe distortion. To cope with these problems and conditions, the manufacturers must employ constant control in each step of the operation involving veneer inspection, resin analysis, with controlled treatment and drying. The multiple-opening laminating-presses of the Parkwood Corporation are equipped with temperature and pressure recording equipment in order to insure proper cure of panels, and periodic checks are made on the rate of heating in the center of thick panels to avoid building up of the temperature by the exothermic resin curing reaction.

Properties of Compreg

The specific gravity of compreg averages 1.35. Thick sections laminated at specific gravities above this point are subject to checking, while an appreciable drop in the specific gravity results in lower physical and mechanical properties.

The water absorption by compreg, determined according to the old Army Air Forces Specification *(1)* (1 by 3 by 3/8 in. specimen, one in. in the fiber direction) after a 24-hr. immersion in water will range, for products of high specific gravity, from less than 1 percent for the best stabilized compreg to 6 percent or more for the less stabilized compreg. In all cases, a decrease in specific gravity will result in increased water absorption.

Because compreg swells so slowly, the old 24-hr. water-absorption test has little meaning. A new rapid equilibrium swelling and recovery test (developed by the U. S. Forest Products Laboratory) is being included in a new specification now in preparation *(1)*. In this test, cross sections 1/8 in. wide by the thickness of the panel and 2 in. long are measured in the thickness direction of the original panel, then soaked in water at 70° F. for 24 hr., and then again measured in the same direction. These thin sections come virtually to swelling plus recovery equilibrium in this period of time. Tests have shown that when the equilibrium swelling plus recovery does not exceed 12 percent increase in thickness, which is the newly specified maximum, the tendency for the particular compreg to washboard in service (exhibit uneven swelling plus recovery) without a surface finish is negligible. Most of the compreg now made in the United States will meet this specification, although the earlier material would not.

Compreg is relatively resistant to decay, termites and marine borers and it is more resistant to acids and mild alkaline solutions than wood, impreg or staypak. The flame resistance of compreg is also considerable and can be further improved by incorporating phosphate salts in the treating solutions.

A high degree of polish can be imparted to any cut surface of stabilized compreg by merely sanding the surface with fine sandpaper and then buffing it. This potential polish exists throughout the structure. All that is necessary to bring it out is to smooth the surface. This easy way of restoring the finish would be an advantageous property of compreg or compreg-faced furniture or flooring. The natural finish is highly resistant to such organic solvents as alcohol and acetone, which destroy most applied finishes.

Compreg has a higher coefficient of thermal expansion than normal wood, largely because of its high degree of compression. The increase is mostly in the direction of compression and is generally about 50 percent. The increase in the thermal-expansion values can be calculated from the resin content and degree of compression *(11)*.

The strength properties of compreg, with the exception of toughness and Izod impact, are increased about in proportion to its increase in specific gravity.

Compreg made with higher resin contents has greater compressive-strength values but lower tensile and Izod impact values *(3)*. Many of the strength properties of compreg, such as the modulus of rupture and the modulus of elasticity in static bending and shear, are but slightly affected by manufacturing variables and degree of cure, whereas the water-resistance properties continue to be improved with a more complete cure *(8)*. The toughness and Izod impact values of compreg, however, vary considerably with variations in the manufacturing technique and curing time *(7)*. For this reason, one of these two tests should be regularly made.

Compreg is from 10 to 20 times as hard as normal wood and is appreciably higher in abrasion resistance.

Specific strength properties of densified wood can be emphasized by varying the grain direction of the laminae. A fishing rod, for example, is produced with a parallel lamination for directional strength, while a forming die is produced with cross grain laminations to provide uniform strength in all directions.

Due to its increased hardness and the presence of resin, compreg is more difficult to machine than normal wood. In appreciable thicknesses, it should be cut with special saws such as those used for cutting brass or plastics. Machine speeds should in general be lower than for cutting normal wood. Compreg machines well and can be turned with greater precision than normal wood on a lathe using metal-working tools.

Compreg is more brittle than normal wood and most metals, although it is considerably tougher than the ordinary molding plastics. Because of its brittleness, objects made from it should have rounded fillets rather than sharp edges. This is true of threads cut in compreg.

Compreg can be glued to itself or to normal wood with both hot-press and room-temperature-setting, nonacidic resin glues. The compreg surfaces to be glued should be lightly sanded to remove the surface gloss before gluing *(10)*, and when the panels are thick, these surfaces should be milled plane so as to assure perfect contact. Glue spreads of 15 to 27 lb. per 1,000 sq. ft. of single glue line should be applied. Gluing pressures should be adequate to get good contact, generally 150 to 250 p.s.i.

Some Applications

Because of its exceptional long wearing qualities, densified wood will be especially valuable in reducing maintenance costs and maintaining quality production. Molds for post-forming plastic laminates, for example, have been made of compreg since they have longer lasting qualities than ordinary wooden molds for extended production requirements.

These same wearing qualities have made compreg valuable in the production of turn tables for rubber extrusions. Turn tables previously made of conventional wood splintered and tore the rubber. The compreg turn tables have such smooth surfaces that production rejects have been greatly reduced.

Picker sticks of densified wood are now supplanting those made of conventional wood in the textile industry because of their superior stiffness and strength. These sticks are subjected to continuous abrasion. Service tests have shown that 600 sticks of densified wood can outlast 12,000 sticks of conventional wood with a saving in cost of 56 percent. In this particular application, production was accelerated because the use of compreg sticks reduced shutdown time. Formerly machinery had to be stopped for one hour to replace the conventional wood sticks.

New beauty has been brought into the most discriminating households with utility items fabricated from densified wood. Cutlery handles and sheaths to grace the dining table, with silent butler and cigarette tray tops that add new warmth to living room accessories, all possess a rich appearance and close-grained beauty that will not be marred by years of service. Smooth handles of this material are also being produced for other home items such as pot and roast stands.

The enviable combination of beauty and strength in densified wood has figured prominently in the production of fishing rods. The durability offered by these rods is evidenced by the many types of service for which they are made. Included are a utility boat and bridge rod, a bait-casting rod, a spinning rod, and light and heavy game rods. They possess the desired flexibility, are virtually impervious to water and weather, and are exceptionally strong, having a tensile strength of 30,000 pounds per square inch, and a flexural strength of 40,000 pounds per square inch.

Other applications now being evaluated for this material include parting boards for foundries and refractories, gymnasium flooring, marine decking, stair treads, doorsills, millwork, and bobbins and shuttles for textile equipment.

Densified wood is a challenge as well as an opportunity for the woodworking industry.

Wherever there is a need for beauty of grain and finish—or service qualities that defy abusive treatment—densified wood will provide a new, and perhaps the final answer.

Properties of Hi-Den

The physical properties of Hi-Den are presented in Table 1.

TABLE 1.—PHYSICAL PROPERTIES OF HI-DEN

Property	No. 111	No. 112	No. 121	No. 431
Specific gravity	1.30	1.30	1.30	1.30
Tensile strength, p.s.i.	35,000	15,000	40,000	35,000
Modulus of rupture, p.s.i.	36,000	20,000	46,000	42,000
Izod impact, ft. lb. per inch of notch	6	3	8.5	7.5
Moisture absorption, 24 hr., percent	2	2	6	3

Standard sheet sizes are 30 by 48 inches up to and including 2 inches thick; 23 by 54 inches up to and including ½ inch thick. To calculate the weight of a given panel, use 20 cubic inches as equal to one pound.

The standard finish is a natural polish. However, panels up to ¾ inch thick can be supplied with one or both surfaces sanded. An extra charge is made for sanding.

Hi-Den is made with a plus tolerance on thickness unless otherwise specified. Closer tolerances than standard can be obtained by sanding. Thickness tolerances for Hi-Den are given in Table 2.

TABLE 2.—STANDARD THICKNESS TOLERANCES FOR HI-DEN

Thickness Inches	Tolerance Inches
1/8	0.125—0.150
1/4	.250— .280
3/8	.375— .410
1/2	.500— .540
5/8	.625— .670
3/4	.750— .800
7/8	.875— .930
1	1.000—1.060
1 1/8	1.125—1.200
1 1/4	1.250—1.350
1 3/8	1.375—1.485
1 1/2	1.500—1.620
1 5/8	1.625—1.750
1 3/4	1.750—1.875
1 7/8	1.875—2.000
2	2.000—2.150

References

(1) Army Air Forces. Spec. No. 15065 (Mar. 1944). No. 15065–B now in preparation.

(2) Bernhard, R. K., Perry, T. D., and Stern, E. G. Superpressed plywood bonded with thermosetting synthetic-resin adhesives. Mech. Eng. 62:189. (Mar. 1940)

(3) Erickson, E. C. O. Mechanical properties of modified wood. Forest Products Laboratory Report R1639. (1947)

(4) Millett, M. A. and Stamm, A. J. Wood treatment with urea resin-forming systems. Modern Plastics 24:150. (Oct. 1946)

(5) ——, ——, Same. Modern Plastics 25:159. (Feb. 1947)

(6) ——, —— Wood treatment with resin-forming systems. Modern Plastics 25:125. (Sept. 1947)

(7) ——, Seborg, R. M., and Stamm, A. J. Influence of manufacturing variables on the impact resistance of resin-treated wood. Forest Products Laboratory Report 1386. (1943)

(8) Seborg, R. M., and Stamm, A. J. Effect of resin treatment and compression upon the properties of wood. Forest Products Laboratory Report 1383. (rev. 1945)

(9) Stamm, A. J. Modified woods. Modern Plastics Encyclopedia. 1948.

(10) ——, and Seborg, R. M. Resin-treated, laminated, compressed wood. Trans. Am. Inst. Chem. Eng. 37:385. (June 1941)

(11) Weatherwax, R. C. and Stamm, A. J. Coefficients of thermal expansion of wood and wood products. Trans. Am. Soc. Mech. Eng. 69:421. (May 1947)

Discussion

Walter Buehler (University of Florida): Do you mean to imply that the wood cell wall itself is actually impregnated?

Mr. McLean: The fact that veneer swells to a greater extent in low polymer phenol formaldehyde resinoids than in water indicates a penetration of cell wall structure. The extent of the penetration is questionable, but the improved moisture resistance and dimensional stability of compreg impregnated with low polymer resinoids over compreg made with resins of larger molecular structure is evidence that the cell wall has been penetrated, stabilized and sealed. Let me refer you to the section "Resins Used" in my paper.

E. A. Behr (Chapman Chemical Company): With reference to Mr. Buehler's statement and Mr. McLean's comments, I would like to add the following: Materials such as pentachlorophenol in oil or creosote are non-swelling solutions; they can enter the pores or cell cavities but not the cell wall proper. Water, on the

other hand, swells wood, which means that the cell wall has been penetrated. If a substance dissolves in water, it may also enter the cell wall provided it is small enough in molecular size to enter the so-called transient capillaries which are opened by the swelling solvent. Resin forming materials can enter these capillaries, but polymerized resins are too large.

Frederick H. Vogel (Alabama Polytechnic Institute): I am interested in the implication that compreg is a new product. I know that it was used 20 years ago by the Westinghouse Electric Company of Pittsburgh. In 1930 it was used to make compreg "hook sticks" for large electric circuit breakers at the Trafford Micarta Works of Westinghouse, and the "wood-Micarta" was not a novelty then.

Mr. McLean: Commercially, compreg is a relatively new material. Before the war, two large electrical manufacturers produced and consumed large quantities for insulating parts where tensile strength, rigidity and moisture resistance were of importance. May I refer you to Column 2 on the first page of my paper?

George M. Hunt (Forest Products Laboratory): I do not believe that the term "compreg" would properly apply to most of the products which have masqueraded under that name.

Mr. Vogel: I know that the old Westinghouse material was made by soaking 1/8- or 1/16-inch wood veneer in an unpolymerized phenol-formaldehyde resin syrup, following which it was dried and then hot-pressed at 2,000 p.s.i. to yield a dense engineering product known as "wood-Micarta". I would call it "compreg" as you define that term today.

Roy Carter (North Carolina State College): Compreg is made to a variety of specifications and it varies greatly in physical properties. It may be made in sizes and strengths suitable for many uses by varying the species, the lamination thickness, the resin impregnant or the pressure, according to its intended use. Some of the notable applications include hardened desk legs, machine parts, finished furniture parts and hammer boards for machine shop drop hammers.

Mr. Hunt: When the speakers state that compreg has been in use in this country and Europe for many years, I think there must be some confusion in terminology. It is true that the impregnation of wood with solutions of polymerized resin, followed by densification has been practiced for a long time both here and abroad but that method does not produce true compreg; the resin does not enter the fine capillary structure, and does not provide the high degree of stabilization characteristic of compreg. It is only when wood is impregnated into the fine capillary structure of wood with a solution of unpolymerized or partly polymerized resin-forming chemicals and then polymerized in place in the wood that the subsequently densified product may properly be called compreg. This is a relatively new material and process that provides improved properties. We know of no record of its commercial use anywhere prior to its public announcement by the Forest Products Laboratory in 1936.

Mr. McLean: Mr. Hunt's comments in essence summarize the statements made in my introduction with emphasis on paragraphs 4, 5, and 6.

Mr. Carter: The strength properties of densified wood shown in Table 1 of Mr. McLean's paper reveal a considerable increase in toughness over the usual resin-impregnated and compressed wood. This improvement is a result of imparting to the treated wood some of the properties of the Forest Products Laboratory's "compreg" and "staypak." By processing at conditions that limit and control the resin content toughness is considerably increased. This manufacturing technique and the improved properties of the densified wood indicate possibilities that this raw material may find new applications.

One attempt to use the compressed wood on maple hammer boards was made about 2 years ago in cooperation with a drop hammer mill in Maine and the Parkwood Corporation. The hammer boards vary from 1¼ inches to 1⅞ inches thick and 8 to more than 10 feet long. Three or four of the boards are placed edge to edge in the drop hammer presses. A set of cam rollers grips the hammer boards to raise the hammer. Pressure of the rollers against the maple compresses the wood and slippage of the rollers causes greater abrasion of the maple boards at the point of press closure. Since compreg is already compressed, we tried facing the hammer boards with ¼ inch of compreg,

thus distributing the load over a larger surface of normal wood.

The average length of life of a set of hammer boards is around 3 days. Crushing the boards and abrasion decrease the width of the hammer boards beyond use and are the main causes of failure.

The compreg-faced hammer boards were so dense that the rollers "slipped" on the hard surface and wore the compreg even faster than normal wood. After 6 hours of continuous service, or one day, the compreg-faced boards in two drop hammer presses were considered unusable. While the compreg faces naturally were not compressed, the abrasion caused by action of the rollers wore the hard surfaces much more than anticipated.

A number of people have inquired about the use of "compreg" and "staypak" for hammer boards. I believe this was the first attempt to make hammer boards out of densified wood.

Mr. McLean: I am wholly in accordance with Mr. Carter's remarks and appreciative of his added and enlightening information.

FOREST PRODUCTS RESEARCH SOCIETY

Wood Preservatives

R. H. Bescher

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The variety of preservatives and fire retardants offered for pressure treatment of wood may confuse the wood user not familiar with the field. No one preservative is ideal for all needs—each has its good qualities and its limitations. This paper is intended to simplify the field by describing the more important preservatives, their applications and limitations.

Introduction

WOOD is the most widely available, adaptable, useful construction material. It is light and strong, easy to work, and decorative in its natural state. By means of pressure impregnation with the proper preservatives it can be given permanence, fire retardance, extra hardness or dimensional stability, making it competitive with manufactured products in fields where untreated wood cannot compete. Pressure impregnation makes sapwood grades and non-durable heartwoods useful for many purposes where they are not satisfactory untreated.

There are many wood preservatives and fire retardants, and no two are exactly alike either in composition or effectiveness. Some are used where only resistance to decay and insect attack are required, while others are for use where cleanliness is of primary importance. Some preservatives are used where both cleanliness and resistance to leaching are necessary.

Since there are so many preservatives, and since the ultimate uses to which treated wood is put are so varied, it is necessary to establish some general classification.

Types of Preservatives

There are four general types of wood preservatives:

1. Standard creosote and creosote-coal tar solutions, for extreme outdoor service conditions, where dark color, distinctive odor, and the lack of paintability are not objectionable. These preservative oils are widely used for piles, poles, posts, ties, and all other wooden items subject to the most severe decay and insect exposure. They are the only preservatives satisfactory for marine installations.

2. Inorganic water soluble salt preservatives. These materials are suitable where leaching is not an important factor, and where cleanliness, lack of odor, and paintability are of primary importance.

3. Organic oil soluble preservatives. These are fairly specialized materials, practically insoluble in water, but sufficiently soluble in other solvents, usually the lighter petroleums, to make a treating solution. Most prominent in this group are pentachlorophenol and copper naphthenate. Wood treated with proper formulations of these preservatives is clean, paintable, and resistant to leaching.

4. Miscellaneous preservatives which do not function primarily to protect wood against decay, insect attack or fire, but impart special qualities, such as increased hardness, dimensional stability, and resistance to acids and abrasion.

Purchasing a wood preservative is like purchasing insurance, in that preservative treatment, like insurance, is not needed when the structure is erected. The preservative adds no utility to the structure during the first portion of its life. Only after an age is reached at which the untreated structure would be excessively costly to maintain, becoming prey to decay and insects, does preservative treatment begin to show its value. Unlike some insurance, from which benefits may never be recovered, preservative treatment invariably "pays off" in lower maintenance costs and extended service life of the treated wood.

Just as the prudent man will not buy insurance from an unknown company, he should not buy wood processed by an unknown method or with an unknown preservative material. The wood preserving industry, through the American Wood-Preservers' Association, has spent

considerable effort in establishing service records for the better known, commercially available wood preservatives. One can look to these records to decide which preservative is best for various applications.

Creosote, Creosote-Coal Tar Solutions, and Creosote-Petroleum Solutions

High-temperature coal tar creosote has been the standard of the preservative oils for over 100 years. It has an enviable record as a wood preservative under the severest service conditions. All authentic creosote-treated woods have given excellent service when treated by standard pressure processes.

Pressure-creosoted wood is dark brown to black in color. The surface of the wood is slightly oily and the material has a pronounced odor. It can be painted only by the use of special sealers. Creosoted wood can be used out-of-doors, subject to weather, without protection of paint. It is used extensively for poles, piles, ties, bridges, platforms, substructures of buildings, etc.

Creosote and creosote-coal tar solutions are the only wood preservatives suitable for marine installations.

Creosote is such a satisfactory wood preservative that it can be diluted for certain applications. For cross ties, piles, and heavy structural lumber it is frequently diluted with admixtures of coal tar, the mother liquor from which creosote is produced.

Creosote-coal tar solutions are generally formulated in one of the following proportions by volume: 80/20, 70/30, 60/40, or 50/50. The majority of treatments are with 70/30 mixtures. These solutions may be substituted for coal tar creosote where oilier and blacker surfaces are not objectionable. They are used extensively for cross ties, land and marine piles, and heavy structural timbers. A 70/30 creosote-coal tar solution frequently gives better performance against Limnoria (one of the marine borers) than does straight distillate creosote.

Creosote-petroleum solutions are used by some of the larger railroads, particularly in the Southwest, for treating cross ties and other structural members. They are generally used in heavier retentions than creosote-coal tar solutions. Use has been restricted to areas where petroleum has a considerable price advantage over coal tar.

Waterborne Inorganic Salts

Waterborne salt preservatives are used where clean, odorless, and paintable wood is required. They are the least resistant class where leaching is a serious factor, but, because their ingredients have a positive affinity for wood, they are more durable than might be expected, considering their original water solubility.

Zinc chloride was the standard waterborne salt preservative for many years. It built up a creditable reputation, even in such extreme uses as railroad ties.

About 15 years ago the permanence of zinc chloride was improved by the addition of sodium dichromate, and more recently, by the further addition of copper chloride. These preservatives are chromated zinc chloride and copperized chromated zinc chloride, the latter of which was announced at the annual meeting of the American Wood-Preservers' Association in April 1949. For decay and insect protection, treating solutions are formulated to impregnate the wood with 1 pound of dry salt per cubic foot of wood.

Wolman Salts is another salt preservative that has been proved by many years of good service against decay and insect attack. Wolman Salts solutions are formulated to impregnate the wood with 0.5 pounds per cubic foot of wood.

Other promising waterborne salt preservatives are being used. Some are proving valuable in specialized uses, but are not commercially available in all parts of the country and have not had time to establish such service records as chromated zinc chloride and Wolman Salts. Among these are Greensalt, Celcure, Chemonite, and Boliden Salts.

Fire Retardants

Wood pressure impregnated with waterborne fire retardant salts has been installed in many military and industrial structures. Severe fires in these structures have shown such wood, when exposed to fire, will maintain its structural strength longer than unprotected steel, will not contribute fuel to a fire, and will not permit the spread of flame over its surface. In

these fires, where treatment records are known, the fire retardants used were chromated zinc chloride, Minalith, or Protexol.

To provide adequate fire retardance, chromated zinc chloride retentions are increased to 3 pounds per cubic foot of wood, by increasing the concentration of the treating solution. The pressure cycle is not lengthened, so the only added expense is the additional material used. A special formulation, Chromated Zinc Chloride (FR), has been developed to improve the protection imparted by this chemical. In either case, extra heavy decay and insect preservative retentions are achieved.

Protexol and Minalith are used in various retentions up to 6 pounds of salt per cubic foot of wood.

Organic Oil Soluble Preservatives

These are relatively new, special purpose formulations, not so widely used as the first two types. In general, they are almost insoluble in water, but are soluble in many petroleum solvents. The toxic portions of these preservative solutions provide decay and insect protection but are not classed as fire retardants. The solvent carriers evaporate from the wood soon after treatment requiring no kiln drying. The relatively non-volatile toxics are left in the wood, which is clean and paintable. The petroleums used as solvents will not alter dimensions or raise the grain of wood.

Copper naphthenate came into prominence in the wood preserving industry during World War II and was used as a toxic agent to fortify petroleums used in admixtures with creosote. If specially formulated, copper naphthenate has been found safe for greenhouse and agricultural applications where other preservatives are either harmful to the plants or not durable enough.

Pentachlorophenol preservatives were first used in the sash, door and millwork industries to prevent stains and molds and give some de-

Modern wood preserving plant and yard.

cay protection where conditions are not severe. They are applied by dipping. When applied by pressure, pentachlorophenol fills a need for a clean-treatment preservative where leaching resistance is important. Its qualities vary with the petroleum used as a carrier, from dark and oily, as creosote, to a clean, paintable wood. This latter quality is the only one with material advantages over established preservatives in the pressure wood treating industry.

Miscellaneous Preservatives

These materials were developed primarily for specialty uses and incorporate the use of water soluble organic resins. Solutions of these resins are injected into wood by means of pressure. The wood is kiln dried, and then subjected to temperatures ranging between 200° F. and 210° F. during which time the resin is cured. This treatment increases the density, dimensional stability, hardness, and abrasion resistance of wood.

Specifications

To insure satisfactory service from preservative treatments, wood should be purchased under standard specifications. Among the best known of these are the specifications of the Federal Government and the American Wood-Preservers' Association. These cover the purchase and preparation of the wood, the treating processes and preservative materials for most purposes. They are revised constantly to include the latest and best in practice and materials. For specialized uses, associations such as the American Railroad Engineering Association and the American Association of State Highway Officials write excellent specifications pertinent to their own fields. A list of some of the preservative specifications is given in Table 1.

It may be noted that there is more than one specification for most of the preservatives. In most cases, specifications for each preservative are identical, indicating that the various associations which formulate them are in agreement on the qualities necessary for the preservative.

Table 2 lists some of the applications where pressure treatment is valuable, with the preservatives and retentions recommended for each.

Conclusions

Creosote and creosote-coal tar solutions are the oldest standard preservatives. Over 100 years of use has proved them best for such extreme exposure conditions as weathering, ground contact, or running water. They are the only preservatives suitable for marine installations.

Waterborne salt preservatives are recommended for wood required to be clean, odorless, and paintable, where leaching is not a serious factor.

Oilborne organic wood preservatives, including copper naphthenate and pentachlorophenol, are desirable for use where leaching is a factor, but clean, paintable wood is desired. Odor from such treatment is slight, but not objectionable in most uses. These preservatives must be properly formulated with carriers that will leave the wood with the desired surface characteristics.

TABLE 1.—PRESERVATIVE SPECIFICATIONS

Preservative	Association Specification				
	American Wood-Preservers' Association	Federal	American Railway Engineering Association	American Society for Testing Materials	American Association of State Highway Officials
Creosote	P1	TT-W-556a	Committee 17	D 390	M133-42
Creosote–Coal Tar Solutions	P2	TT-W-566a	Committee 17	D 391	M133-42
Creosote–Petroleum Solutions	P3, P4	TT-W-568	Committee 17	----------	M133-42
Chromated Zinc Chloride	P5	TT-W-551	----------	----------	M133-42
Wolman Salts Tanalith	P5	TT-W-573	----------	----------	M133-42
Pentachlorophenol Preservatives	P8	TT-W-570	----------	----------	--------
Copper Naphthenate Preservatives	P8	----------	----------	----------	--------
Fire Retardant Chemicals	----------	Navy 51-C-38	----------	----------	--------

Industrial building, showing use of fire retardant timber in trusses, purlins, and roof planking.

Discussion

John H. Sweeney (Aetna Plywood & Veneer Company): As a plywood selling organization, we are interested in fireproofing plywood to meet building code requirements for interior partition. Low cost is important if we are to compete with plaster. What is the answer?

Mr. Bescher: Most of the present day building codes do not distinguish between fire retardant and untreated wood. Building codes which exclude wood as partition material likewise exclude fire retardant treated wood. This is primarily due to the lack of knowledge of the value of fire retardant treated wood by the writers of codes.

There is also another problem in connection with plywood, and that is that the plywood sheets must be glued before they are treated. Fire retardant salts, in general, interfere with the gluing of veneers.

Walter Buehler (University of Florida): I want to call attention to the fact that we can and do vary the retention of preservatives and fire retardant salts according to the use to which the treated wood is applied. In many applications, the depth of penetration is more important than the retention and that is a point which some of us may overlook. I believe that your tables of recommended retention might well be scrutinized and modified in part.

Mr. Bescher: I agree with Mr. Buehler that penetration is equally as important as the specified retention and that it had been assumed that in the use of the table that good commercial treating practice would be followed. (A footnote has been added to the table to indicate that the wood is to be processed in accordance with the A.W.P.A. standards, which assures good distribution of the specified preservative.)

TABLE 2.—SOME APPLICATIONS WHERE PRESSURE TREATMENT IS VALUABLE

Material	Species, Preservative and Recommended Retentions of Preservative			
	Oak	Pine	Fir	Miscellaneous
Bridges, Trestles and Tipples				
Decking	6 # C[1]	8 # C	6 # C	8 # C—Gum
Pile Foundation	10 # C or Ccts[2]	12 # C or Ccts	10 # C or Ccts	----------
Structural Timbers	6 # C or Ccts	8 # C or Ccts	----------	----------
Ties	6 # C or Ccts	8 # C or Ccts	----------	----------
Cooling Towers				
Boards, Framework, Framework Support, Trays	----------	8 # C	6 # C	6 # C—Redwood
Farm Buildings				
Hog Houses, Corn Cribs, Silos, Feeders, Corrals	----------	8 # C or 8 # Penta[3]	----------	----------
Fences				
Post, Rails, Gates	----------	8 # C or 8 # Penta	----------	----------
Flat, Coal, Gondola Car Lumber				
Decking	6 # C or 8 # Penta	8 # C or 8 # Penta	----------	6 # C or 8 # Penta—Gum
Siding, Slats, Etc.	6 # C or 8 # Penta	8 # C or 8 # Penta	----------	6 # C or 8 # Penta—Gum
Highways				
Guard Rails	----------	8 # C or 8 # Penta	----------	----------
Guard Rail Posts	----------	8 # C or 8 # Penta	----------	----------
Planking, Decking, Etc.	6 # C	----------	----------	8 # C—Gum
Industrial Buildings, Bins, Sheds				
Floor Blocks	----------	8 # C	----------	----------
Pile Foundations	----------	12 # C or Ccts	10 # C or Ccts	----------
Roofing Plank	----------	Salts*	Salts*	----------
Structural Members and Lumber Above Ground	----------	Salts*	Salts*	----------
Structural Members and Lumber Below Ground	6 # C or Ccts	8 # C or Ccts	8 # C or Ccts	----------
Mines				
Air Shafts	----------	Salts*	----------	----------
Car Lumber	6 # C	----------	----------	----------
Cribbing	6 # C or 6 # Ccts	8 # C or Ccts	----------	----------
Retaining Walls	6 # C or 6 # Ccts	8 # C or Ccts	----------	----------
Stairs, Elevator, Shafts, Fire Doors	----------	Salts*	Salts*	----------
Ties	6 # C or 6 # Ccts	----------	----------	----------
Timbers, Props, Etc.	----------	8 # C	----------	----------
Piers, Docks, Wharves—Marine				
Decking, Walkways	----------	8 # C	8 # C	----------
Jetties	10 # C or Ccts	16–24 # C or Ccts	12–14 # C or Ccts	----------
Piles	----------	16–24 # C or Ccts	12–14 # C or Ccts	----------
Structural Members	----------	16–24 # C or Ccts	12–14 # C or Ccts	----------

TABLE 2.—SOME APPLICATIONS WHERE PRESSURE TREATMENT IS VALUABLE—Continued

Material	Species, Preservative and Recommended Retentions of Preservative			
	Oak	Pine	Fir	Miscellaneous
Platforms				
Flooring, Supports, Railing, Strips		8 # C or 8 # Penta	6 # C or 6 # Penta	
Hand Rails		Salts[4] or 8 # Penta	Salts or 6 # Penta	
Power and Transmission				
Conduits		8 # C or 8 # Ccts		
Cross Arms		6 # C or 6 # Penta	6 # C or 6 # Penta	
Guy Posts		8 # C or 8 # Penta		
Poles		8 # C	8 # C	
Railroad and Siding Materials				
Box and Refrigerator Car Lumber		Salts	Salts	Salts—Gum
Conduits		8 # C or Ccts		
Cribbing	6 # C or Ccts	8 # C or Ccts		
Culverts	6 # C or Ccts	8 # C or Ccts		
Cross-Switch Ties	6 # C, 6 # Ccts, 8 # C-P	8 # C, 8 # Ccts, 12 # C-P[5]		8 # C, 8 # Ccts, 12 # C-P Misc. Hardwoods
Sign Boards				
Posts		8 # C or 8 # Penta	6 # C or 6 # Penta	
Boards, Braces, Framework		Salts or 8 # Penta	Salts or 6 # Penta	
Tanks, Sumps, Vats				
Pile Foundations		10 # C or Ccts	8 # C or Cts	
Roof		8 # C or 8 # Penta	6 # C or 6 # Penta	
Miscellaneous				
Barges and Other Service Boats	8 # C or Ccts			
Greenhouse Lumber		5 # CN[6]		
Piles, Land	10 # C or Ccts	12 # C or Ccts	10 # C or Ccts	
Piles, Marine	Refusal—C or Ccts	16–24 # C or Ccts	12–14 # C or Ccts	
Posts		8 # C or 8 # Penta		
Racing Stables, Paddocks, Etc.		Salts[5]	Salts[5]	
Vineyard Posts and Arbors		6 # C or 8 # Penta		

[1]C—Creosote.
[3]Ccts—Creosote–Coal Tar Solution.
[3]Penta—Pentachlorophenol, used in 5 percent solution.
[4]Salts—Chromated Zinc Chloride, Copperized Chromated Zinc Chloride or Wolman Salts. Recommended retentions per cubic foot of wood are 1 lb. for Chromated Zinc Chloride and Copperized Chromated Zinc Chloride, 0.5 lb. for Wolman Salts. [5]Indicates fire retardant treatment; recommended retention per cubic foot is 3 to 6 lb. (Chromated Zinc Chloride, Chromated Zinc Chloride (FR), Protexol and Minalith).
[5]C-P—Creosote–Petroleum Solution.
[6]CN—Copper Naphthenate, used in 10 percent solution.

Note: The above material should be treated in accordance with the A. W. P. A. specifications T-1 through T-8 for the material and preservative involved.

H. W. Angell (American Lumber & Treating Company): I want to confirm Mr. Bescher's remark that the user should rely upon the standard preservative and treating specifications of the American Wood Preservers' Association.

Ira Hatfield (Monsanto Chemical Company): In speaking of the use of pentachlorophenol in oil for the pressure treatment of wood, the statement is made that if certain petroleum oils are used as carriers, clean, paintable wood can be obtained and that their qualities are the only material advantages over established preservatives. I believe that there are several other advantages. Pentachlorophenol furnishes a definite and measurable quantity of preservative value: the percent of toxic chemical in wood can be measured. Furthermore, there are research records to back up the belief that pentachlorophenol when used with coal-tar creosote will act as a synergist and actually increase the preservative value of either product used separately.

Another characteristic of pentachlorophenol in oil solutions not exhibited by coal-tar creosote is the tendency for the toxic principle to distribute itself in the wood after the treating process has been completed. This is of especial interest in such woods as Douglas fir, which does not take treatment easily.

Mr. Bescher: I do not wish to get into a long discussion of the points you raise, but it is my belief that not every technologist agrees on all of them. In my opinion, pentachlorophenol is an excellent preservative when properly used, but there is much about the limitations of its use that we have yet to learn. Our company is promoting and selling pentachlorophenol for those applications to which it is peculiarly suited, but I want to repeat that not everyone in the wood preserving industry will agree with Mr. Hatfield concerning the several claims for superiority of pentachlorophenol.

FOREST PRODUCTS RESEARCH SOCIETY

Wood Boring Beetles That Damage Furniture and Interior Woodwork

Ira Hatfield

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Suppliers of wood products as well as the general public know that certain insects attack wood, but neither group is sufficiently acquainted with the insects or with control methods. This paper describes some of the common beetles, as well as the damage they do to wood. It also tells what measures can be taken to prevent their damage and gives specific control measures. Examples of the types of insects involved are enumerated in order to make possible linking entomological information with control information given in the paper. A bibliography is appended.

Introduction

UNLESS proper precautions are taken, furniture and wood used in the construction of dwellings and other buildings are subject to the attack of several insect enemies. Important among these insects are subterranean termites (often improperly called "white ants"), dry wood termites, and various families of beetles belonging to the order *Coleoptera.*

This paper makes no attempt to cover the two types of termites, but is limited to the description and discussion of control measures for some of the more important wood boring beetles. Although some of the insects described are primarily forest insects, the larvae may continue to live in the wood after seasoning, and may therefore be important in construction wood as well as in furniture.

Although there is no accurate way to obtain figures on the actual dollar damage caused by wood boring beetles each year, it is well known that they cause many millions of dollars worth of damage each year to the wood in houses, furniture, implements, sporting goods and other wood items. It is also well known that the manufacturers of these products as well as the general public are usually inadequately acquainted with either the insects that cause the damage or the methods of preventing or of stopping the damage. Unfortunately, the presence of powder post and other beetles in wood is generally not discovered until the damage has advanced to a serious degree. It means little to discuss preventive measures then—the money will have to be spent on control measures and repairs, and that price will be high compared to what prevention would have cost. Not that preventive measures are not essential to continued control, but preventive measures will not solve the problem of wood already infested.

In order to know how to prevent damage by or how to control intelligently the beetles discussed in this paper, it is necessary to be familiar with their habits and with the type of damage they cause. Methods of preventing attack as well as methods of controlling these insects will be discussed.

Lyctus or True Powder Post Beetles

These beetles are the ones most often brought into homes in hardwood flooring and in furniture, especially the rustic furniture purchased along the roadside. Often the wood shows no evidence of insect damage, and, for that reason, the householder is unaware of the infestation until little mounds of frass (often referred to as "little piles of powder or sawdust") begin to appear on the rough surfaces of boards, on the floors in houses or in bureau or buffet drawers or other places (Fig. 1).

How did the wood become infested and what is the damage like? The adult *Lyctus* beetles, which range in color from reddish-brown to black and in size from about 3/32 to 7/32 inch in length (Fig. 2), are often present in sawmill and lumber yards and around furniture factories. The female beetles seek out the open-pored seasoned wood and deposit their eggs in the pores by forcing the eggs into the pores. This is important to remember, for it indicates why woods with certain pore sizes, such as ash, oak, hickory and walnut, are attacked, and it also gives a clue as to how to prevent *Lyctus* damage. *Lyctus* eggs are not

Fig. 1.—Frass on surface of wood—a visual sign of powder post beetle activity.

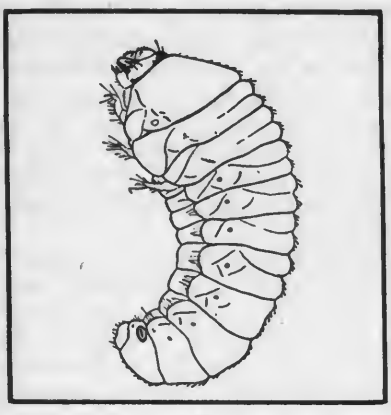
visible to the naked eye, and so the initial attack goes unnoticed. In 6 to 15 days after the eggs are laid in the wood pores they hatch and the young larvae (grubs or worms) which emerge begin eating their way into the wood away from the wood surface. Their presence also goes unnoticed.

These larvae are white in color except for the dark brown head and mouth parts, and when full grown they are about 1/32 inch long (Fig. 3a and 3b). The front (anterior) end of the larva is relatively larger than the rear (posterior) portion, and the last pair of breathing pores (spiracles) at the posterior end of the body are much larger than the other spiracles. The size of the last pair of spiracles, distinguishes the *Lyctus* larvae from the larvae of other wood-boring insects. The larvae have three pairs of four-jointed minute legs on the anterior portion of their bodies.

Courtesy USDA Bur. Ent. & Pl. Q.

Fig. 2.—Photograph of adult *Lyctus planicollis* Lec. beetle. (Enlarged about 16 times)

The length of time the larvae remain in the wood as larvae depends upon the specie of *Lyctus* beetle as well as on the abundance of starch in the wood available for food. Wood having a high starch content is ideal for rapid development of the larvae, and under these conditions some species can completely mature in 3 months while others require 9 months or longer. During all of this time, these busy little larvae are actively burrowing in the wood in order to obtain more of the starch for food. As the wood substance passes through the



a.

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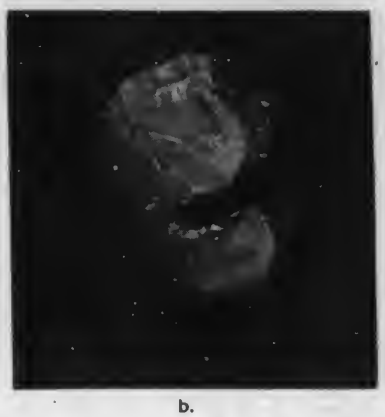
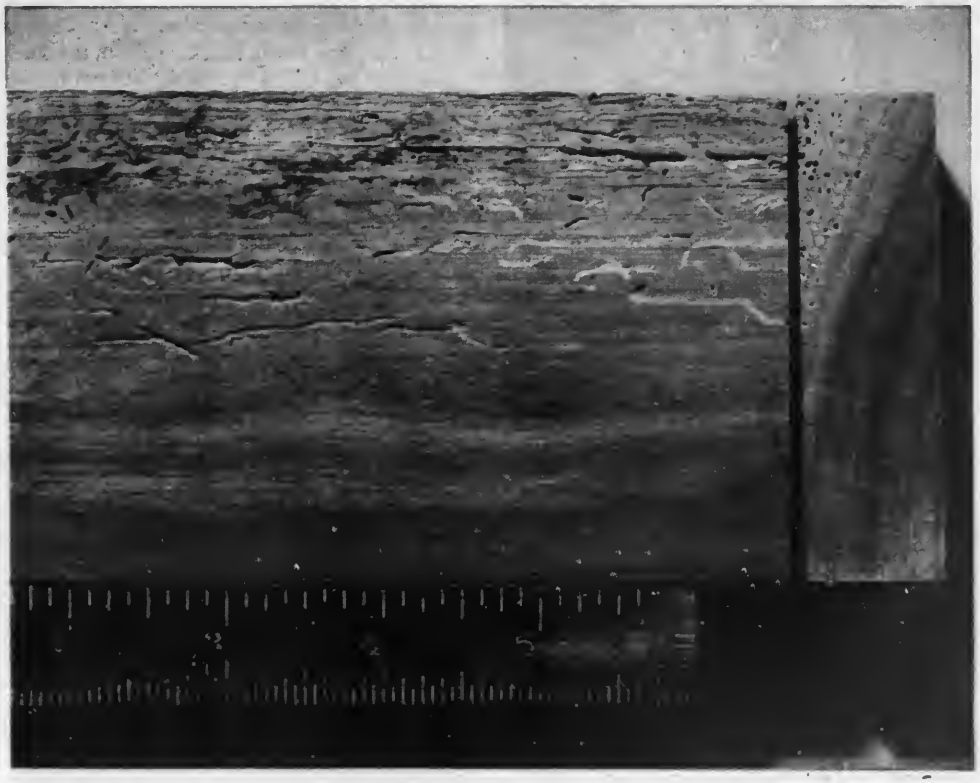


b.

Courtesy USDA, Bur. Ent. & Pl. Q.

Fig. 3.—a. Drawing of *Lyctus* larva showing enlarged eighth spiracle. (Approximately 20 times natural size.)
b. Photograph of *Lyctus* larva. (Approximately 20 times natural size.)



Courtesy Forest Products Laboratory.

Fig. 4.—Side and end grain of black walnut wood showing typical *Lyctus* damage to sapwood.

Fig. 5.—Piece of wood split to show complete destruction of interior portion by *Lyctus* larvae, three of which can be seen in the photograph.

larva's body, the starch is extracted, and the remaining wood substance is ejected from the larva and completely fills the galleries behind the larva. Once the larva becomes full grown, it usually bores to within 1/8 inch of the wood surface, and there makes a small chamber where it changes from the larval (worm) stage to the adult (beetle) stage. When that change takes place is usually when the telephone starts to ring or the letters start to come in, for the adult beetle bores to the surface of the wood and pushes the mounds of frass out onto the floor, and it is then that an awareness of the presence of the beetles occurs. The only wood eating done by the adult is the eating of its way out of the wood; all other wood damage is produced by the larvae. When the adults emerge, they fly around, mate, and the female beetles lay eggs in wood cracks or crevices or in the old emergence holes and the cycle starts over again. Typical damage to wood in which *Lyctus* larvae and adults have been active is illustrated in Fig. 4. Although the appearance of infested wood depends upon the age and intensity of infestation and upon the species of beetles involved, the interior of the wood always shows the presence of the frass-filled galleries and the outside is likely to show the exit holes.

In the early stages of attack the action of the larvae takes place almost exclusively along the grain of the wood and primarily in the springwood, but as the attack continues the tunnels or galleries run in any and all directions, and ultimately the entire sapwood can be reduced to a powder (Fig. 5). The exit holes made by the adult beetles range in size from about 1/32 to 1/16 inch in diameter. They are round except in those cases where the wood is cut after emergence of the beetles, and then the holes may be elongated or other shapes.

Infested timber, furniture, or other wood is usually detected by the presence of small piles of frass on the wood surfaces or on the floor surfaces or beneath wood areas infested by the beetles. In log cabins the frass may outline on the floor the pattern of the framework overhead. The frass usually appears during the period of greatest activity of the larvae in the wood. At those times the frass is pushed out of the exit holes or out of small holes where the larvae have eaten completely to the surface of the wood. The frass also appears when the adult beetles emerge from the wood.

Lyctus larvae have not been found either in poorly seasoned wood (moisture content over 40 percent, oven dry basis), or in wood dried below 8 percent moisture. Furthermore, they do not tend to attack old wood as do the *Anobiid* beetles. So far as finished wood products are concerned, they are most often found in such places as newly laid hardwood floors, in stored merchandise, such as in tool handles, sporting goods (tennis racquets, golf clubs, canoe paddles), gun stock blanks, wagon wheels, bamboo or similar products, and in furniture made from infested wood stock.

It should be emphasized that unless wood is chemically treated with proper chemicals, the larvae may work in the wood for long periods of time if the starch content of the wood is low. It should also be borne in mind that as the

adult beetles leave the wood, they can bore through varnish, paint or other coatings, and through fabrics and various floor coverings.

Control of *Lyctus* Beetles

To tell a potential home owner to select a house with hardwood floors with a low starch content or to select furniture made from wood with a low starch content would be absurd. Likewise, to tell a furniture manufacturer or flooring company to use only certain species of wood or those cut at only a prescribed season of the year would be impracticable. The old recommendation of sorting out infested stock and burning it is also impractical, except in those cases where the wood is damaged beyond use. It is true that infested wood should be removed and treated or burned to prevent further infestation, but not all infested wood needs to be burned.

What then can be done to help protect all concerned from the ravages of these beetles? The answer will have to be two-fold: in some cases preventive measures can be taken, in others only remedial measures will suffice. In far too few cases has the item of *prevention* of beetle attack been taken into consideration. In any storage area, every effort should be made to remove infested lumber. Once the infestation is eliminated, the lumber should be stacked in such a way that the oldest material is always used or removed first. No untreated susceptible lumber should remain static for long periods of time. This is not the only important sanitation measure to be watched. Scrap wood and trimmings around the yard or wood working plant should be removed or burned.

Storage conditions and sanitation are not the only places where preventive measures can be practiced. In the United States, practically no attention has been given to the preservative treatment of furniture, flooring and other susceptible wood for the express purpose of preventing insect infestation, and still less attention has been given to the treatment of lumber in the unseasoned stage. Although certain water soluble chemicals, such as borax, and certain suspensions of materials, such as colloidal sulfur, have been demonstrated to be effective against *Lyctus* beetles, their use has not been common in the United States. It is understandable why water-borne materials have not been popular for the treatment of seasoned wood, for such treatments require the additional expense of redrying the lumber. For the application of either of the above two mentioned chemicals to green lumber, it has been customary to obtain the surface protection by dipping the lumber for at least 15 seconds in a hot (180° F.) 5 percent solution of borax, or for a similar period in a 190° F., 2 percent suspension of micro-fine sulfur.

It is known that filling pores of susceptible but uninfested species of wood with varnish, paint or wax helps prevent the adult beetles from laying their eggs in the wood pores. It is also known that certain chemicals applied to the wood after cutting, framing, planing, or otherwise preparing the wood for use, will protect that wood against *Lyctus* beetles.

Turpentine or mixtures of turpentine and kerosene (usually in the ratio of 9 to 1) have long been used by furniture manufacturers. So far as the writer can find, there are no published records on how long these materials will actually afford protection.

A very penetrating and effective chemical for killing all stages of *Lyctus* beetles in infested wood is orthodichlorobenzene. The material can be used straight or in a 50–50 mixture with a light petroleum oil. Such solutions can be applied to wood before fabrication, or to finished wood items to which fabrics or other materials have not been attached. If these materials are applied over finished surfaces, the finish is likely to be damaged, but the wood can later be refinished as the materials volatilize from the wood. Although these materials kill the various stages of the *Lyctus* beetle, they do not impart a lasting protection.

In recent years it has been demonstrated that oil formulations containing 2 percent to 5 percent of pentachlorophenol will not only kill *Lyctus* beetles, larvae, and eggs, but that they render the wood immune from their ravages for prolonged periods of time. Such a treatment also imparts protection against certain other insects, and when water repellents are added to the solution, some degree of dimensional stability is also obtained.

Seasoned lumber, furniture squares, implement handles, and other wood products, when dipped in a 5 percent solution of pentachlorophenol in a suitable solvent for as little as one

minute, will receive a good *surface* treatment. Where the stock is heavily infested and where depth of penetration is desired, seasoned stock up to 4 inches thick should be submerged in a 5 percent solution of pentachlorophenol in a light oil for at least 5 minutes. Larger stock will require longer immersion periods. Infested furniture which is not upholstered can also be given a spray treatment with a 5 percent solution of pentachlorophenol in oil. Remarks relative to the safe handling of chemicals will follow the general discussion of the beetles.

To date, the most practical method of treating powder post beetle-infested hardwood floors is to apply an oil solution of pentachlorophenol to the floor by means of a spray. In some cases, 15 percent by volume of trichlorobenzene has been added to a 5 percent solution of pentachlorophenol in petroleum oil and with good results. Brushing tends to "roll" the varnish and should not be used. Mopping is likewise not recommended. If the spray solution is applied by means of a spray under low pressure (not over 40 pounds pressure) and with the nozzle about 3 inches from the surface of the wood, generally good results have been obtained. The spray solution should never be "fogged" into the room. Application should be made from one corner or side of the room and in such a manner that the operator does not have to walk on treated areas. Likewise, the occupants of the house should not use the room until the solvents have volatilized and the floor is again "dry." Applications should be thorough, but not so heavy that the solution runs between the boards or "lakes" or "puddles" on the floor.

There are many kinds of floor finishes and each may react differently to oil solutions. It is therefore always desirable to apply a small amount of spray solution in an inconspicuous place, such as an area covered by a rug, and observe the effects before the total surface is treated.

Thus far we have discussed only chemical methods of controlling *Lyctus* beetles. Infested lumber, furniture or other items could be given a heat treatment. Although kiln drying can generally be practiced only by sawmills or wood-working plants, heat chambers have been used by Pest Control Operators and others to kill *Lyctus* infestations. When heat chambers are used, there is always the possibility of damage due to the loosening of joints, warping of wood, or the ruining of fabrics or finishes. Where heat is employed, it is necessary to give consideration to the temperature used, the humidity in the chamber, the thickness and kind of wood, and the particular item being given the heat treatment. The thickness of the wood has a direct relationship to the heating period required, for there is a lag between the heating-chamber temperatures and the temperatures attained in the interior of the wood. Remarks relative to heat treatments as well as the use of fumigants will be found near the close of the article under the heading, "General Remarks Relative to Preventive and Control Measures."

Bostrichids—False or Large Powder Post Beetles

These beetles (also known by the common names of branch or limb borers), in direct contrast to *Lyctus* beetles, are much larger, ranging from 1/8 inch to one inch in length, compared to 1/6 inch or less for the Lyctids. Although there is some variation in color depending upon the species involved, these beetles are generally dark brown to black in color. The adult Bostrichids are easy to differentiate from the Lyctids because their body is cylindrical rather than flat and the thorax (the middle one of the three body segments) extends out over the head, making the body appear to have only two body segments (Fig. 6).

The eggs of Bostrichid beetles are not laid in the surface pores of wood as is the case in the *Lyctus* beetles, nor are the eggs laid in sur-

Courtesy USDA, Bur. Ent. & Pl. Q.

Fig. 6.—Photograph of the Bostrichid beetle *Xylobiops basilaris* Say.—the red-shouldered shot-hole borer. (About 10 times natural size.)

face cracks or crevices as in the case of the Anobiid beetles, which will be discussed later. In the case of Bostrichid beetles, the adult beetles bore into the wood and the female lays eggs in egg tunnels prepared by adult beetles or in pores leading from the egg tunnels. The larvae, which hatch from the eggs, are also capable of producing tunnels in the wood. Since both the adult beetles and the larvae bore into the wood, the galleries formed vary in size and shape. The tunnels prepared by the adult beetles tend to follow the soft springwood areas in the longitudinal direction of the wood. The egg tunnels are usually at right angles to the main tunnel system. These tunnels are kept free from frass. In contrast, irregular longitudinal burrows made by the larvae are filled with frass, which varies from a very fine to coarse texture and tends to stick together rather than fall apart or powder as does the frass of the *Lyctus* beetles.

The larvae of Bostrichids are found primarily in the sapwood of hardwood species, although the sapwood of softwoods is not immune to the attack of certain species of Bostrichids. In general, the larvae tend to move only in a longitudinal direction in the wood, eating their way in the sapwood. The full grown larvae are curved and wrinkled, are yellowish to white in color, and lack "hairs" or spinules (asperites) on the upper surface of their bodies. The spiracles are all about the same size, the last or posterior pair not being larger than the others (Fig. 7). They have three pairs of five-jointed legs.

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Fig. 7.—Larvae of the Bostrichid beetle *Xylobiops basilaris* Say. (Enlarged 9 times.)

The larvae depend upon starch for their development, and the length of their existence as larvae is therefore dependent upon the quantity of starch present in the wood. When full grown the larvae pupate (undergo a transformation from a larva to an adult form), and when the transformation is complete, the adult beetles bore to the surface of the wood and emerge.

The holes formed in the wood by the adult beetles are circular in shape and vary from 1/8 to 3/8 inch in diameter. Wood that has been infested by Bostrichid bettles before cutting, however, may show elongated holes due to the fact that the wood is not always cut at right angles to the direction of the galleries.

Control of Bostrichid Beetles

Since the Bostrichid beetles do not depend upon the pores of wood to start their infestation, it will be immediately recognizable that the preventive measures used against *Lyctus* beetles will not work for the Bostrichid beetles. Closing the wood pores prevents *Lyctus* attack, but actual poisoning of the wood is necessary if Bostrichids are to be kept out of wood. The most useful chemical found to date for this purpose is pentachlorophenol applied in a suitable petroleum oil carrier. This material is toxic to both adults and larvae and will give a lasting protection to wood properly treated with it. The notes given under control of *Lyctus* beetles on application of such chemicals to wood products apply in this case as well, and will therefore not be repeated.

Anobiid Beetles or Furniture and Death-Watch Beetles

The adult Anobiid beetles usually appear in the warm summer months, although they can appear any time that the temperature and moisture conditions are favorable. Because they are about the same size and color as many other beetles that do not attack wood, their presence is often ignored. The adult furniture beetles vary in size according to species, ranging from 1/10 to 1/5 inch in length. In general, they are reddish- to blackish-brown in color. The

Death-Watch beetles are somewhat larger, averaging ¼ to ⅓ inch in length and are brown to dark brown in color.

The eggs of Anobiid beetles are laid in cracks or crevices or in old emergence galleries, preferably in old wood. As mentioned for the *Lyctus* beetles, this suggests a method of control, for since the Anobiid beetles require rough surfaces in which to lay their eggs, it has been found that wood which has its pores filled with paint, varnish, or other agents *before* the infestation takes place, will be less subject to attack than unfinished rough wood. The eggs hatch in a few weeks and the grubs or larvae begin to burrow or tunnel into the wood.

The condition of wood inhabited by Anobiid beetles depends upon the age of infestation and the extent of the damage done. In the early stages of attack, the galleries (which are never visible on the outside of uncut wood), usually follow the grain of the wood, i.e., they will be found only in the softer rings of the wood (springwood). As the infestation spreads, the larvae cut across the grain, giving the wood a honeycombed effect. As the larvae mature into adult beetles, they emerge from the wood, leaving circular exit holes which range from 1/16 to ⅛ inch in diameter (Fig. 8).

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Fig. 8.—Photograph showing *Anobium*-infested chair leg. (Natural size.)

The larvae can live in both coniferous and hardwood material and in either heartwood or sapwood. Since the larvae may vary in appearance according to their age, only mature larvae will be described. The full-grown larvae are curved and wrinkled, and some of the folds on the body have rows of tiny dark-brown spinules or asperites ("hairs") which probably help the grubs move in their tunnels (Fig. 9). The

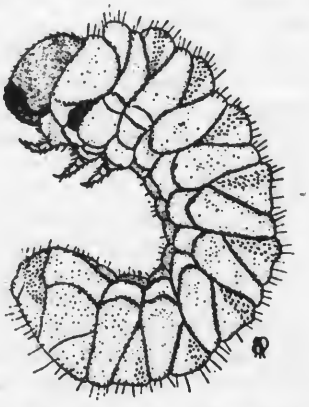

Fig. 9.—Full grown larva of Anobiid beetle *Xestobium rufovillosum* DeG. (About 7 times enlarged.) (After Parkin.)

larvae have three pairs of short five-jointed legs. Although the larvae vary in size depending upon age and species, in general the full grown larva of the common furniture beetle *Anobium punctatum* DeG is about ¼ inch in length, whereas the average length of the death-watch beetle *Xestobium rufovillosum* DeG larva is about 2/5 inch.

The galleries produced by the Anobiid larvae are packed with coarse frass. This frass or excreta ranges from coarse, undefined shapes to small pellets having rather well defined shapes. In some species the pellets are somewhat bun-shaped, in others they are elongate, while in others they may taper at each end and may be non-uniform in shape. Generally they lack in-

dentations or other sculpturing on their surface (Fig. 10), and this feature helps differentiate them from the pellets of dry-wood termites (Fig. 11).

Courtesy USDA, Bur. Ent. & Pl. Q.

Fig. 10.—Elongate excreted pellets of digested wood from burrows of Anobiid beetle *Nicobium hirtum* Ill. (Enlarged about 9 times.)

Fig. 11.—Pellets of dry-wood termites showing rounded ends and longitudinal depressions. (Enlarged approximately 9 times.) (Photo by N. Piesbergen.)

The larvae may work in the wood from one to several years. When they become full grown, they tunnel toward the surface of the wood, and there construct an oval cell in which they pupate and then transform into adult beetles. The period of transformation may take two or three weeks, after which the beetles may bore to the surface of the wood and escape, or, if it is winter, they may remain as adults in the wood until more favorable conditions for emergence exist.

Control of Anobiid Beetles

We have already mentioned that since the Anobiid beetles require rough surfaces in which to lay their eggs, it is possible that unfinished surfaces of desks or other furniture could be treated with pore fillers or other materials to prevent attack if the manufacturers of such furniture desired to do so or if the public demanded it. Since Anobiid beetles can work in any species of wood and often attack rough lumber, such lumber could be given a chemical treatment with pentachlorophenol in oil, and infestation thus prevented.

In view of the fact that *preventive* measures are seldom taken, our discussion of the elimination of Anobiid beetles from infested wood might be divided into their control in "stationary" habitats, such as the woodwork of buildings, and their control in "movable" objects, such as furniture, implements, etc. In buildings, structurally weakened timbers or other items should be replaced, preferably with wood treated with chemicals known to be effective in controlling the beetles. Although kerosene or other petroleum oils, orthodichlorobenzene, and trichlorobenzene have been suggested for this use, because of their relatively rapid volatilization, they do not possess lasting qualities and therefore do not give more than temporary protection. The most useful material found to date for treating wood in place consists of a 5 percent solution of pentachlorophenol in petroleum oil. This material may be applied by brushing or spraying, the latter generally being more successful.

For treating infested "movable" objects, such as lumber, furniture, implement handles, etc., chemical applications may be practicable, or heat treatments can be used if heat chambers are available. Pentachlorophenol in suitable petroleum oils is probably the most useful chemical for treating seasoned wood, the method of application depending upon the items treated.

Naturally, implement handles, gun stocks, etc. could be dipped, whereas furniture would have to be brushed or sprayed. Since heat treat-

ments must either be severe or of long duration if lower temperatures are used, the applicator must recognize the danger of warping the wood, loosening the glue joints, or otherwise adversely affecting wood if heat is to be considered.

Cerambycids or Longhorn Beetles

These beetles are not apt to infest wood in homes, but the larvae can be brought in in wood items, and they may remain active and damage the wood for several years.

Although the adult longhorn beetles usually lay their eggs in crevices or cracks in bark, certain species such as *Chion cinctus* Drury can lay their eggs either on the surface of bark or of wood. The oval, long or spindle-shaped, glassy-white eggs may hatch in a few days, or a longer time may be required if climatic conditions are not ideal.

The larvae of Longhorned Beetles need never be confused with the larvae of other powder post beetles, for they are easily distinguishable and are all quite similar in general shape and appearance. The larvae or grubs are long and narrow and are a light cream color. The body is composed of a number of rings or segments, generally tapering somewhat from front to rear (Fig. 12). The head does not appear to be a separate segment, due to the fact that it is often partly withdrawn into the first body segment. Often the only distinguishable features of the head are the heavy dark-brown jaws. Although many of the larvae are legless, some have a pair of very minute, short legs on the lower surface of each of the first three segments behind the head. Also, some of the segments contain "warts" or "bumps" which undoubtedly aid the larvae in moving in the tunnels. The full grown larvae vary from ½ to 3 or 4 inches in length, depending upon the species.

Although most longhorned beetles seem to prefer moist wood for their rapid development, the larvae have been known to work in wood paneling and heavy wood furniture for long periods of time. Lawn furniture, picnic tables and similar items seem to be favorite haunts for this group of insects. As the larvae reach full maturity, they pupate and then transform to beetles. At the time of pupation, the mature larva gnaws a special chamber in the wood and there goes through its pupal and adult changes, which usually requires a relatively short period of 3 to 4 weeks.

The adult longhorned beetles are large, conspicuous insects ranging from ¼ to 3 inches in length, and are easily distinguishable by the length of their "horns" or antennae. In some species the antennae of the males may be much longer than the body itself (Fig. 13). Many of the species contain conspicuous color markings, which are bound to attract attention. One of the most common longhorned beetles is the old house borer. It is ¾ to 1 inch long and is black with grey markings on its wing covers, which appear as two traverse grey bands.

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Fig. 12.—Larva of the Cerambycid round headed borer beetle *Megacyllene antennatus* White (Enlarged three diameters).

As previously mentioned, damage to timbers by longhorned beetles is caused entirely by the larvae; the adult beetles do not bore into the wood. In general, damage is confined to the sapwood, but in species of wood such as ash and hickory in which the sapwood and heartwood are not closely defined, the damage may be found in all portions of the wood. The galleries produced by the Longhorn larvae are

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Fig. 13.—Photograph of the longhorned beetle—*Neoclytus caprea* Say. (Enlarged 4 times.)

irregular and packed with frass, which varies from flour-like powder in the case of some species to very coarse frass in other species.

Because there is such a variation in the size of the Longhorn beetles and larvae, it is difficult to describe accurately the type of damage done by each unless the damage is described for each particular species. Likewise, the exit holes vary greatly in size according to species, ranging from round holes 1/8 inch in diameter to round holes as large as 1/2 inch in diameter.

Wood containing some bark is often attacked, and the holes in the bark or the engravings on the wood where the bark has dropped off help identify and locate the damage.

Control of Cerambycids

Since damage by some longhorned beetles like the ash borers, originate in green or partly seasoned wood, control of these insects must start in the forest or at the sawmill seasoning yard. In cases where this type of longhorned beetle appears in old houses or around the household, re-infestation is not likely unless more freshly cut or partially seasoned wood is present. To aid in preventing infestation by some other species of beetles, the bark should be removed from the edges of boards or from logs in cabins attacked by longhorned beetles. On wood where bark is absent, application of chemicals is usually unnecessary, but if the client demands that the wood be given a treatment, oil solutions of pentachlorophenol are most likely to succeed in killing the adults and larvae and in preventing re-infestation, and of course will provide protection against many other kinds of beetles.

In the case of longhorned beetles like the "flat oak" and "old house" borers that attack seasoned wood, it has been observed that these beetles are controlled by a preservative treatment such as 5 percent pentachlorophenol in oil. Since specific suggestions on methods of treatment of infested wood have been given previously and will be more fully discussed in the following section dealing with preventive and control measures, further comments on the control of Cerambycids will not be given here.

General Remarks Relative to Preventive and Control Measures

In general, preventive measures for protecting wood and wood products against the four groups of insects discussed above should be taken before the wood items reach the home owner or householder. Green or seasoned wood should be protected before the wood is used.

The use of chemicals and of heat has been suggested. It might seem that the control measures given for each group of insects made reference too often to the use of pentachlorophenol in oil. If there were other usable products that would impart prolonged protection, they should have been mentioned, but the literature reveals no product that will give prolonged protection and equal in effectiveness to pentachlorophenol. Borax and colloidal sulfur do have use, but being the type that require water applications, they do not have the universality of application that pentachlorophenol does.

Orthodichlorobenzene and trichlorobenzene will kill all stages of these insects, but they have no residual effect and will not impart long time protection. Dinitrocyclohexylphenol has also been tested, but it imparts a yellow color to wood and thus is limited in usefulness. Turpentine and certain waxes also furnish an initial protection, but the period of protection is questionable.

Since treatment of infested wood by the pressure method is usually impracticable, immersion of the wood in suitable chemicals usually gives the next best treatment. For items that cannot be immersed or for those which have been finished in some manner before the infestation has been discovered, spraying is the most useful method for applying the solutions to the wood although brushing or mopping and even fumigation has been used.

Some Pest Control Operators have reported control of larvae and beetles by fumigation with cyanide gas, methyl bromide, and chloropicrin. Little data are available on this subject, but it has been stated that for fumigating with methyl bromide, two cubic centimeters of liquid gas per cubic foot of chamber space for 18 hours at 80° F. should be used for 2 inch or smaller sizes of wood.

If the choice of treating method lies between spraying, brushing or mopping, it will generally be advantageous to use a spray as a more thorough job can be done without adversely affecting the finish. Whereas varnished and painted surfaces might be ruined by brushing pentachlorophenol solutions onto wood, spray treatments when carefully applied penetrate the wood without "roughing" the finish. Where sub-floors, floors, joists, or girders are sprayed, it has been found that a nozzle which delivers a conical type spray is most useful. Likewise, it has been found that the spray nozzle should be held about 3 inches from the surface being sprayed. If held closer than 3 inches the solution "bounces off" the wood; if held farther away than 3 inches the spray fogs and much is lost. Where hardwood floors are to be treated, the operator should start in a corner or a side of a room away from the door and work toward the door so that he will not have to walk on the treated areas. In general 24 to 48 hours should elapse before anyone walks on the treated floors. Applications should be made so that the surfaces are adequately "wet" with the solution but there should not be so much solution applied, that the material "puddles" or "lakes" on the floor surface.

Although considerable work has been done to determine the temperatures required per units of time and thickness of wood to kill infestations of powder post beetles in wood, that information has not been translated into furniture or other manufactured items. This fundamental work of Snyder and St. George and its extension by Fisher and Parkin was combined in one table by St. George as shown in Table I.

TABLE I.—SCHEDULE FOR HEATING WOOD TO CHECK DAMAGE BY POWDER-POST BEETLES

Relative humidity (per cent)	Lethal temperature required	Thickness of timber	Time required to overcome lag after kiln has attained lethal temperature	Additional margin of safety	Time then held at lethal temperature	Total period of exposure after kiln has attained required conditions
	°F	Inches	Hours	Hours	Hours	Hours
100	130	1	½	½	1½	2½
		2	2	½	1½	4
		2½	3½	½	1½	5¼
		3	4½	½	1½	6½
80	125	1	½	½	2	3
		2	2	½	2	4½
		2½	3¼	½	2	5¾
		3	4½	½	2	7
	120	1	½	1½	6	8
		2	2	1½	6	9½
		2½	3¼	1½	6	10¾
		3	4½	1½	6	12
	115	1	½	7½	30	38
		2	2	7½	30	39½
		2½	3¼	7½	30	40¾
		3	4½	7½	30	42½
60	125	1	½	1	4	5½
		2	2	1	4	7
		2½	3¼	1	4	8¼
		3	4½	1	4	9½
	120	1	½	2	7	9½
		2	2	2	7	11
		2½	3¼	2	7	12¼
		3	4½	2	7	13½
	115	1	½	9	36	45½
		2	2	9	36	47
		2½	3¼	9	36	48¼
		3	4½	9	36	49¼

Precautions That Will Help Obtain Trouble-Free Results

Throughout the paper, care in the use of any treatment has been stressed. Heating can loosen joints or warp wood; fumigation can ruin fabrics and must be used with adequate health precautions, and other chemicals must be applied with understanding. In making applications of chemicals to wood by immersion, dipping, brushing or spraying, the person making the application should be adequately protected from the vapors of the chemicals and to prevent the solutions from contacting the skin. In general, goggles should be worn and synthetic rubber gloves should be provided, and a respirator is often essential to an operator's comfort. Any petroleum solvent, regardless of whether it has a low or high flash point, presents a certain degree of fire hazard. Smoking should not be allowed around the premises and care should be taken that open flames are not present. The mist from the spray should be kept off lighted electric bulbs as the droplets that fall on the hot glass make pin-point holes in the bulbs and thus burn them out quickly. It must also be understood that practically all chemicals possess some odor.

It is always desirable, if a finished floor is to be treated, to try a small floor section before the entire area is treated. Such an area may be located in an "under the rug" area or some other inconspicuous place. It must be recognized that there are almost as many floor finishes (varnishes, lacquers, paints, waxes, stains, etc.), as there are floors, and it is impossible to make a definite statement relative to the possible damage that might be done by a spray solution. Likewise, care must be exercised that a spray material is not applied so heavily that it runs down through the floor cracks and thus stains plaster or other areas immediately underneath the treated floor.

It should be mentioned that the spraying of oil solutions in basements or other areas where ventilators are present in the foundation, or the treatment of floors in the house with the windows open, may make it possible for the tiny oil droplets to "drift" out of the openings and on to the shrubbery outside the house. If 5 percent pentachlorophenol in oil hits such shrubbery it can very easily be the cause of leaf drop or even the killing of certain plants. Extreme care in preventing this "drifting" should be exercised by the person making the application.

These rules are not intended to make the task seem difficult, but rather to stress the fact that knowledge makes it possible to get a job done well without injury to people or property.

Examples of Wood Boring Beetles Discussed in This Paper

Often a person who finds beetles working in floors, furniture or other wood items, collects one or more specimens of the beetles or larvae and sends them to a State or the Federal government for identification. In the reply, the entomologist may give the technical name of the insect and send a leaflet describing the general group of insects to which the particular insect belongs.

In order to make it possible to tie such technical names with this article so as to receive the benefit of the specific discussion on each group of insects, we will list here some of the more common insects found in the United States that fit into each group.

Some common *Lyctus* beetles:

Lyctus planicollis Lec.
Lyctus parallelopipedus Melsh
Lyctus brunneus Steph.
Lyctus cavicollus Lec.

Examples of Bostrichid beetles:

Xylobiops basilaris Say.—Red-shouldered shot-hole borer.
Polycaon stouti Lec.
Dinoderus minutus Fab.
Stephanopachys rugosus Oliv.

Examples of Anobiid beetles:

Old furniture beetles

Anobium punctatum DeG.
Nicobium hirtum Ill.

Death watch beetles

Xestobium rufovillosum DeG.
Hadrobregmus carinatus Say.
Hadrobregmus gibbicollis Lec.

Other Anobiid beetles

Trypopitys sericeus Say.
Xyletinus peltatus Harris

Some common Cerambicid beetles:

Smodium cucujiforme Say.—Flat oak borer or flat powder post beetle.
Neoclytus caprea Say.—Grey banded ash borer.
Neoclytus acuminatus Fab.—Red-headed ash borer
Chion cinctus Drury
Homaleum rufulum Hald.
Hylotrupes bajulus L.—Old house borer.
Megacyllene antennatus White—Round headed borer.

Literature References

Anon. The Kiln Sterilization of *Lyctus*-infested Timber. Leaflet 13. Forest Products Research Laboratory, Princes Risborough, Aylesbury Bucks, England. 1938.

Anon. Beetles Injurious to Timber and Furniture. Department of Scientific & Industrial Research. Forest Products Research Bulletin No. 19. 36 pages. Illus. 1940.

Boving, Adam G. and F. C. Craighead. An Illustrated Synopsis of the Principal Larval Forms of the Order Coleoptera. Monograph published by Brooklyn Entomological Society. (Out of Print). 351 pages, 125 plates. Brooklyn, N. Y. 1931.

Cann, F. R. Experiments in Great Britain with Wood Preservatives for the Prevention of *Lyctus* Attack. Forestry 14 (1): 27–30. 1940.

Christian, M. B. Chemical Dips Tests Against *Lyctus* Powder-Post Beetles. Southern Lumberman 159 (2000): 105–109. 1939.

Christian, M. B. *Lyctus* Beetle Damage Prevention. Southern Lumberman 16 (2021): 47–49. 1940.

Christian, M. B. Biology of the Powder-Post Beetles, *Lyctus planicollis* LeConte and *Lyctus parallelopipedus* (Melsh.) Part 1. Louisiana Conservation Review 9 (4): 56–59. 1940.

Christian, M. B. Powder-Post Beetles and Their Control and Notes on Chlorinated Phenols as Soil Poisons for Termite Control. Pests and Their Control 13 (6): 20. 1945.

Cummings, J. E. and J. B. Wilson. The Preservation of Timber Against the Attacks of the Powder-Post Borer (*Lyctus brunneus* Stephens) by Impregation with Various Chemicals. Jour. Council for Sci. & Ind. Res. 9 (1): 37–56. 1936.

Fisher, Ronald C. *Lyctus* Powder-Post Beetles. Department of Scientific & Industrial Research. Forest Research Bulletin No. 2. 46 pages. Illus. 1922.

Fisher, Ronald C. Timbers and Their Condition in Relation to *Lyctus* Attack. Forestry 2 (1): 40–46. 1928.

Fisher, Ronald C. Chemical Preservation of Timber—The Control of Wood-Boring Insects. The Chemical Age 52 (1348): 373–378. 1945.

Fisher, R. C., F. R. Cann, and E. A. Parkin. A Survey of the Damage Caused by Insects to Hardwood Timbers in Great Britain. Dept. Sci. and Ind. Res. Forest Products Research Bull. No. 16. pp. 1–27. 1932.

Kofoid, Chas. F., et al. Termites and Termite Control. U. of Calif. Press. Second Ed. Revised. Berkeley 1940. (Especially Chapter 32 by Edwin C. Van Dyke entitled "Wood Boring Insects Whose Appearance or Workings Resemble Those of Termites") pp. 351–363.

Krogh, P. M. D. and F. G. C. Tooke. Pentachlorophenol Solutions for the Preservation of Wood. Farming in South Africa. Vol. 20; pages 761–769, Pretoria, South Africa. 1945.

Linsley, E. Gorton. The Recognition and Control of Death-Watch, Powder-Post and False Powder-Post Beetles. Pests and Their Control 11 (3): 11–14, 23–25. 1943.

Maxwell–Lefroy, H. The Treatment of the Death-Watch Beetle in Timber Roofs. Jour. Royal Soc. of Arts. 72 (3720): 260–266. 1924.

St. George, R. A. Protection of Log Cabins, Rustic Work and Unseasoned Wood From Injurious Insects. U.S.D.A. Farmers' Bulletin No. 1582. 22 pages. Illus. 1943.

Snyder, T. E. Powder-Post Beetles and Their Control. Pests and Their Control 12 (4): 8, 27–31. 1944.

Snyder, T. E. Defects in Timber Caused by Insects. U.S.D.A. Bulletin 1490, pp. 1–47. 1927.

Snyder, T. E. Preventing Damage by *Lyctus* Powder-Post Beetles. U.S.D.A. Farmers' Bulletin 1477, pp. 1–12. 1926.

Snyder, T. E. and R. A. St. George. Determination of Temperatures Fatal to Powder-Post Beetle, *Lyctus palicollis* (Leconte), by Steaming Infested Ash and Oak Lumber in a Kiln. Jour. Agri. Res. 28: 1033–1038. 1924.

Tooke, F. G. C. and M. H. Scott. Wood Boring Beetles in South Africa. Preventive and Remedial Measures. Union of South Africa Dept. of Agriculture and Forestry. Bulletin No. 247. (Entomology Series No. 14.) Pretoria. 1944.

Discussion

Fred Gottschalk (American Lumber & Treating Company): Could powder post beetle attack be mistaken for termite damage?

Mr. Hatfield: No, not to one familiar with the activities of each. Most of the wood borers produce frass (wood powder), while subterranean termites do not. There are also other distinguishing characteristics.

Mr. Gottschalk: Will not all the standard treatments mentioned by Bescher prevent powder post beetle damage as well as termites and decay?

Mr. Hatfield: Probably yes, but some preservatives are more effective than others, and some cannot be used because of color, odor, or other characteristics.

Robert A. Zabel (New York State College of Forestry): Do the chemicals that you recommend for control of powder-post beetles have a repellent or a toxic action on the insects?

Mr. Hatfield: Repellents are not generally used because they impart only temporary protection. Chemicals are usually selected that have a toxic effect on both eggs and larvae.

R. Joseph Kowal (U.S.D.A. Bureau of Entomology): Dry wood termites might possibly be confused with powder post beetles in California. Even some furniture woods are occasionally bothered out there, although oak is not attacked.

Mr. Hatfield: That is correct. In my previous comments I referred only to subterranean termites.

E. A. Behr (Chapman Chemical Company): Are long-horned beetles able to penetrate heartwood? My reason for asking is that we have seen ash logs with many grub holes running in a ring around the log, extending in toward the center of the log about one or two inches. From this it would appear that only sapwood was attacked, provided long-horned beetles actually were the insects involved. The grub holes were about ¼-inch ovals and were packed with sawdust; no adults were seen.

Mr. Hatfield: Long-horned beetles can also work in the heartwood of species like ash and hickory where the heartwood and sapwood are not clearly defined. Their chief damage, however, is to sapwood.

Bror L. Grondal (University of Washington): How would you advise treating axe handles to protect against powder post beetle attack?

Mr. Hatfield: Pentachlorophenol in proper solvents (either petroleum products alone or mixed with other solvents) has been successfully used.

Ignition Temperatures of Fireproofed Wood, Untreated Sound Wood, and Untreated Decayed Wood

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About 5,000,000 board feet of lumber and timbers are being chemically fireproofed every year by the vacuum-pressure process of impregnation. During the peak war year the demand was 12 times as great.

Whereas fireproofed wood has been adequately evaluated by large-scale tests, very little work has been done in determining the temperatures at which it will ignite. This paper gives ignition testing procedures and results for (1) wood pressure-treated with three commercial chemical formulations, (2) untreated sound wood, and (3) untreated decayed wood.

It was found that upwards of 3 pounds of dry fireproofing chemicals per cubic foot of wood are needed to increase the ignition temperature above 1200° F. The ignition temperature of matched, untreated wood was found to be 400° F., while decayed wood burned at 300° F.

Introduction

THE term "fireproofed wood" refers to wood that has been chemically impregnated under pressure to increase its fire resistance. Fireproofing compounds consist of various proportions of sulphates and phosphates of ammonia, borax, boric acid, zinc chloride, and sodium dichromate. These chemicals, when used in proper proportions and quantities, increase fire resistance to a point at which the material will not support its own combustion; in short, if the source of heat is removed, treated wood will cease to burn, and afterglow will stop quickly. Fireproofed lumber will char at high temperatures, but will effectively resist flame spread and flame penetration.

The vacuum-pressure equipment needed for fireproofing wood is practically the same as that needed for treating with toxic salt preservatives; therefore, many wood preservers are producers of fireproofed lumber. The fire-retardant treatment of wood has been performed in this country for over 50 years, but not until the beginning of the recent war did it become nationwide. The banner year was 1943 when more than 65,000,000 board feet of lumber and timbers were processed, most of which was used for military construction. After the war, when army and navy demands lessened, commercial production leveled at about 5,000,000 board feet per year.

Large-scale tests best determine the effectiveness of fireproofed wood against both flame penetration and flame spread. Resistance to flame penetration is referred to as "fire resistance" and is measured by the time required for a standard test fire to break through a partition or a door made of treated wood. Partitions are tested in accordance with the American Society for Testing Materials "Fire Tests of Building Construction and Materials," (A.S.T.M. Designation E119–47) and doors in accordance with "Fire Tests of Door Assemblies," (A.S.T.M. Designation E152–41). The ratings assigned are in hours and fractions of an hour such as a ¾-hour door or a 1-hour wall.

Flame spread is referred to as "fire hazard" and is measured by the Underwriters' Laboratories, Inc. "Fire Hazard Classification Test of Building Materials." Products are considered as building materials rather than structural units and are assigned fire hazard numerical classification ratings based on a range of 100 (combustible) to 0 (incombustible).

In addition to large-scale proving methods, there are several small-scale testing techniques. The most important are the "fire-tube test" and the "crib test." The fire-tube test is listed by the American Society for Testing Materials as "Combustible Properties of Treated Wood by the Fire-Tube Test Method," (A.S.T.M. Designation E69–47). The crib test is known as "Fire Retardant Properties of Wood," (A.S.T.M. Designation E160–46). The criterion for these laboratory tests is weight loss after exposure to a standard flame. Sometimes

they are used to sample commercial cylinder charges of fireproofed lumber, but the results obtained have only limited reliability; there is too much dependent on the particular pieces selected, and it is impossible to refer to any piece as being "representative of the charge."

Ignition Tests

During the past 30 to 40 years occasional techniques were developed to determine ignition temperatures of various types of wood, treated and untreated.[1, 2, 3] Unfortunately, no truly standard ignition test for wood was ever devised and the results of these methods are difficult to compare and evaluate. Factors which may affect the ignition temperature are (1) the air supply surrounding the wood at the time of test and the rate of air movement, (2) how the heat is applied, whether by slowly heating or by suddenly subjecting the specimens to high temperatures, and (3) how the investigator defines ignition. Generally speaking, the various species are similar in respect to ignition temperatures although their subsequent resistance to flame penetration and flame spread may be slightly different.

This paper gives ignition testing procedures and results for (1) wood, pressure treated with three commercial chemical formulations, (2) untreated, sound wood, and (3) untreated, decayed wood. As a result, it was possible to compare (1) the effectiveness of the three chemical formulations with each other, (2) fire-retardant wood with untreated and decayed wood, and (3) untreated sound wood with untreated decayed wood.

Test Procedure and Criterion for Ignition

After reviewing past literature, it was decided that the most reliable ignition test for comparing fireproofed and untreated wood would be the sudden subjection of test specimens to predetermined temperatures. The apparatus, as shown in Fig. 1, consisted of an

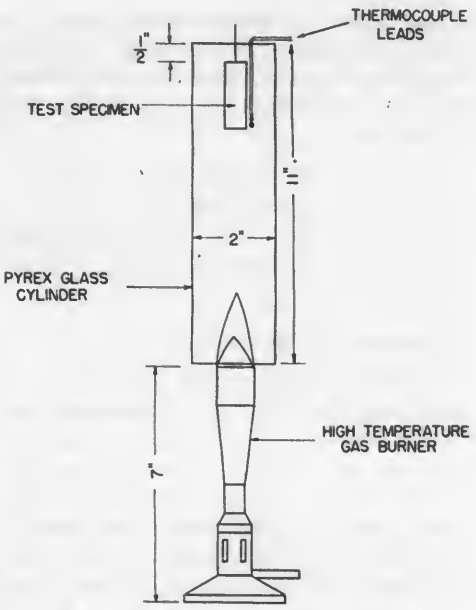

Fig. 1.—Apparatus for ignition tests.

ordinary high temperature gas burner 7 inches high with a 30 mm. grid top. A pyrex glass chimney 2 inches in diameter and 11 inches long was placed over the burner. The specimens were suspended from the top of the chimney, and the lower side of each specimen measured 2½ inches from the top of the cylinder. The distance of the tip of the gas flame from the specimen varied 2 to 6 inches depending on the test temperature. Temperatures were controlled by means of a thermocouple placed inside the chimney near the lower end of the specimen.

After preliminary work a program was outlined to test specimens treated with the heavier retentions of fire-retardants at temperatures from 600° to 1400° F. The specimens were exposed for 1 minute which was enough time for them to become engulfed in flame. They were then removed and the criterion for ignition was as follows: If flaming stopped within 20 seconds and if afterglow ended in less than 20 seconds beyond the flame, specimens were considered not ignited. If either flaming or afterglow, or both, persisted for more than 20 seconds, specimens were considered ignited.

The untreated samples were exposed to temperatures from 275° to 425° F. which required

[1] McNaughton, G. C. "Ignition and Charring Temperatures of Wood," Forest Products Laboratory Mimeo. No. R 1464, Nov. 1944.

[2] Prinse, R. E. "Tests on the Inflammability of Untreated Wood and Wood Treated With Fire Retarding Compounds." National Fire Protection Association 1915 Proc.

[3] Underwriters' Laboratories, Inc., Chicago, Illinois. "Wood. Ignition of, at Low Temperatures." Card C 60, Card Data Service.

a longer time for ignition to take place. The pieces were allowed to remain in place until they became ignited, but if they did not burn after 20 minutes they were considered as non-combustible.

Specimens treated with lower retentions of chemicals were tested from 300° to 700° F.; from 300° to 400° F. they received prolonged exposure, and from 400° to 700° F., 1-minute exposure.

Preparation of Specimens

All wood samples, except decayed and redwood pieces, were cut from a single, clear 1 in. by 6 in. S4S all-sapwood southern yellow pine board having about 12 annual rings per inch. Those that were decayed came from a board having about the same growth characteristics, but having an advanced case of brown rot. Redwood was cut from a clear, all-heart 1-inch board having about 50 rings per inch. All pieces measured ½ in. by ¾ in. by 2 in. long.

The three chemical formulations used for treating are given in Table 1. Treating was done in an experimental cylinder by the pressure process. Weights before and after treatment were used to determine the absorption of chemical solution and net dry retention. Six specimens, numbered 1 through 6, were treated for each retention of each chemical formulation, and then were dried in an oven at 140° F. to 7 ± 3 percent moisture content at which condition all testing was performed. Treating results are given in Table 2.

Results

The results for all the ignition tests are tabulated in Table 3. The ignition temperatures, based on the criterian as given, are readily found for each retention of each chemical

TABLE 1.—FIRE-RETARDANT FORMULAS USED FOR TESTS

Formula	Chemicals	Percentage
Minalith	Ammonium sulphate	60.0
	Diammonium phosphate	10.0
	Sodium tetraborate, anhydrous	10.0
	Boric acid	20.0
		100.0
Chromated zinc chloride	Zinc chloride	81.5
	Sodium dichromate	18.5
		100.0
Chromated zinc chloride (with ammonium sulphate and boric acid added)	Zinc chloride	65.2
	Sodium dichromate	14.8
	Ammonium sulphate	10.0
	Boric acid	10.0

Note: Minalith is also known as Type 2 Fire-Retardant of Navy Department Specification 51C38, Jan. 3, 1944, Chemicals, Fire-Retardant, for Lumber and Timber.

Chromated zinc chloride is also known as Type 4 Fire-Retardant of Navy Department Specification 51C38, Jan. 3, 1944, Chemicals, Fire-Retardant, for Lumber and Timber.

TABLE 2.—TREATING RESULTS

(Retention of dry chemical in pounds per cubic foot of wood)

Series	Concentration of solution	Minalith — Specimen No. 1	2	3	4	5	6	Average
	(percent)							
A	10.0	2.70	2.36	2.28	2.25	2.26	2.27	2.35
B	20.0	5.22	5.16	5.12	5.07	5.00	4.92	5.10
		Chromated zinc chloride						
C	3.0	0.72	0.75	0.76	0.71	0.74	0.76	0.74
D	6.0	1.66	1.59	1.62	1.55	1.56	1.59	1.60
E	10.0	2.59	2.60	2.60	2.65	2.65	2.67	2.63
		Chromated zinc chloride (with ammonium sulphate and boric acid added)						
F	10.0	2.71	2.68	2.66	2.64	2.62	2.60	2.65

formulation as well as for the untreated and decayed specimens. They are as follows:

	Ignition Temperature, °F.
Treated specimens	
Minalith, 2.35 lb. treatment	1200
Minalith, 5.10 lb. treatment	1400
Chromated zinc chloride, 0.75 lb. treatment	350
Chromated zinc chloride, 1.60 lb. treatment	700
Chromated zinc chloride, 2.65 lb. treatment	900
Chromated zinc chloride (with ammonium sulphate and boric acid added), 2.65 lb. treatment	1000
Untreated specimens	
Sound southern pine	400
Sound redwood	400
Decayed southern pine	300

Fig. 2 shows the results for the treated specimens in graph form with ignition temperature plotted against retention of chemicals. Fig. 3 shows the results for the untreated and decayed specimens in bar chart form.

Conclusions

From the data obtained the following conclusions are made:

1. Fire-retardant chemicals increase the ignition point of wood; the amount by which the ignition temperature is increased over similar untreated wood depends upon the particular chemical formulation used and the retention. It is apparent that upwards

TABLE 3.—RESULTS OF IGNITION TESTS

Exposure temperature	After 1 minute exposure		After 1 minute exposure	
	Flaming	Glowing	Flaming	Glowing
°F.	sec.	sec.	sec.	sec.
	Minalith (Moderate Treatment)		Minalith (Heavy Treatment)	
800	0	0	--	--
900	0	0	0	0
1000	0	0	0	0
1100	10	0	0	0
1200	98	0	0	0
1300	55	0	0	0
1400	--	--	22	0
	Chromated zinc chloride (0.75 lb. Treatment)		Chromated zinc chloride (1.60 lb. Treatment)	
400	---	---	0	0
500	116	17	19	0
600	127	100	12	10
700	123	178	2	62
	Chromated zinc chloride (2.65 lb. Treatment)		Chromated zinc chloride (With ammonium sulphate and boric acid added) (2.65 lb. Treatment)	
600	0	0	--	--
700	0	0	0	0
800	0	0	0	0
900	2	25	0	0
1000	40	152	23	0
1100	71	190	92	0
1200	--	--	120	0

Exposure temperature	After prolonged exposure Time before flaming began	After prolonged exposure Time before flaming began
°F.	sec.	sec.
	Chromated zinc chloride (0.75 lb. treatment)	Chromated zinc chloride (1.60 lb. treatment)
300	Did not flame	
350	157	Did not flame
375	120	Did not flame
	Untreated southern pine	Untreated redwood
375	Did not flame	Did not flame
400	427	125
425	252	115
	Rotten southern pine	
275	Did not flame	
300	105	

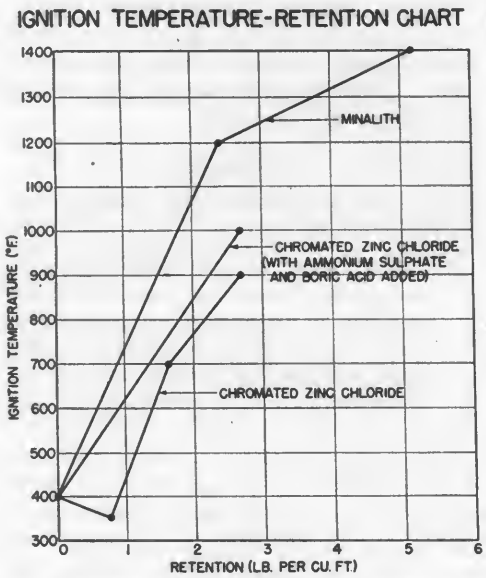
IGNITION TEMPERATURE-RETENTION CHART
IGNITION TEMPERATURE (°F.)
RETENTION (LB. PER CU. FT.)
MINALITH
CHROMATED ZINC CHLORIDE (WITH AMMONIUM SULPHATE AND BORIC ACID ADDED)
CHROMATED ZINC CHLORIDE

Fig. 2.—Relation of amount of chemical retained to ignition temperature of wood.

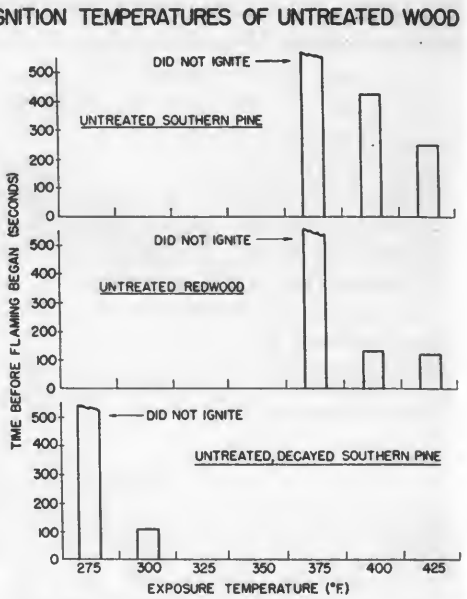

Fig. 3.—Ignition characteristics of untreated sound redwood and southern pine and untreated decayed southern pine.

of 3 pounds of dry chemical per cubic foot are needed to increase the ignition temperature above 1200° F. More than 4 pounds are needed to increase it above 1300° F.

2. Fire-retardant chemicals in retentions of 1 pound or less apparently do not bring about any increase in ignition temperature.
3. Untreated southern pine and untreated redwood have about the same ignition temperature although the redwood ignited quicker than the southern pine under the prolonged exposure test.
4. Untreated decayed wood will ignite at a much lower temperature than similar sound wood.

Discussion

G. G. Sward (National Paint, Varnish & Lacquer Association): How would you distinguish between the terms "flame-proof" and "flame-resistant"?

Mr. Angell: The terms are used interchangeably. The Underwriters Laboratories have, on occasion, made reference to flame- or fire-proof as meaning wood that has been chemically impregnated by pressure.

Pit U. Desjardins (International Plywoods, Ltd.): I am interested in this problem because our company manufactures birch panels. Have any methods been developed to make wood flame resistant without at the same time affecting the natural beauty of the wood?

Mr. Angell: Yes, several fire retardant treatments are colorless; after the wood is dried, it looks almost like it is untreated.

Bror L. Grondal (University of Washington): It appears as though regulations, restrictions and specifications covering flame proofing are too severe, and they are taking away some of our legitimate markets for wood. Why can't we have a more reasonable interpretation of the subject?

Mr. Angell: What you say may be true. However, the Underwriters Laboratories have a standard testing procedure on a large-scale basis and I believe they tested most of the commercial formulations. They give each treatment a numerical classification rating based on 0 for incombustible and 100 for combustible (as obtained with untreated red oak). The architect or engineer may then select a treatment according to what he thinks is necessary. Heavy treatment may not be necessary in many cases.

Mr. Grondal: The Underwriters Laboratory does not recognize "fireproof wood". I think we could work for that recognition.

Mr. Gottschalk: During the war we were able to turn out flame-proofed lumber for the Navy at a cost of $30 to $40 per thousand board feet. The Navy specification called for resistance to a temperature of 1800° F. for 3 minutes. There could be no glow persisting for more than 20 seconds. Those specifications were too rigid and they required too much chemical to be economically feasible except for the military. One of the worst features of these Navy specifications was that it set a precedent.

Armin Elmendorf (Elmendorf Research Incorporated): Several years ago we were given the assignment of developing fireproof plywood panels for use as bulkheads or partitions in ships and Pullman cars. We experienced no great difficulty in producing plywood having excellent fire-resistance by using some of the conventional salts used for fireproofing wood, but the potential users objected to the pungent fumes generated when the plywood was exposed to flames. I should like to raise the point whether sufficient attention is being given to this liability of wood that has been treated to make it fire-resistant?

Mr. Angell: The Underwriters Laboratories have not overlooked this point in testing commercial formulations. As far as I know, all the formulations tested showed less smoke in the fire test than untreated wood.

Mr. Boehm: As a result of tests made during the war, the Navy considered cellulose itself among the most toxic materials from the standpoint of noxious gases emitted at high temperatures.

Mr. Behr: Tests were made by the Bureau of Ships during the war on analysis of gases from burning wood and from heated fire-retardant treated wood. As I remember the results, the gases from the untreated wood contained more toxic agents than those from the fire-retardant treated wood.

Mr. McLean: The choice of treating chemical will depend on the expected highest temperature and the actual use of the treated lumber.

Mr. Sward: It has been proven that the vapors from burning paint and other chemicals used to treat and preserve wood are not as dangerous as wood vapors themselves.

Wood Waste Disposal and Air Pollution Control in the Los Angeles Area[1]

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and

Louis M. Rosnick

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The intensification of the air pollution problem in the Los Angeles basin combined with a comprehensive set of regulations regarding air pollution adopted by the 1947 California Legislature have focused attention on waste disposal methods used by wood-working plants in the area. Cheap oil fuels make the use of wood waste for fuel purposes uneconomical and incineration is the common disposal method. Incomplete combustion during incineration is the primary cause of pollution by such plants. Analysis is made of the quantity of wood waste, methods of disposal, principles of combustion and incinerator design, better operation of existing equipment, and conversion and reduction of waste.

The Frame of Reference

AIR pollution has a long but somewhat dishonorable history. As far back as 1661, Sir John Evelyn had written an extensive analysis of the effects of London's smoky atmosphere on the population and had made comprehensive, if perhaps unrealistic, suggestions for cleaning it up *(1)*.

In the United States, smoke regulations have been in force for over a hundred years and there are over 75 municipal control ordinances on the books *(2)*. The National Institute of Municipal Law Officers has published a model ordinance to be used whenever another community decides it should do something about controlling atmospheric pollution *(3)*.

The most recent and most comprehensive attempt to deal with air pollution is taking place in California at the present time. Although Los Angeles has long suffered from smoke nuisance and although a considerable body of statute and case law has grown up attempting to circumscribe it, the nuisance from atmospheric contamination by fumes, gases and dusts in recent years has become quite intolerable. The term "smog" has been applied to this complex of atmospheric contamination which frequently limits visibility to a few blocks and causes irritation of eyes, nose and throat.

Natural Conditions Favoring Air Pollution in the Los Angeles Area

Topography and meteorological conditions have a great influence on air pollution in the Los Angeles basin. (For this reason what is said here may not necessarily have general application) *(4)*. High mountain ranges surround its basin on the north and northeast. Prevailing winds during most of the year are westerly or northwesterly during the day time. The average wind velocity is less than six miles per hour. These on-shore "sea breezes" move gently over the area from approximately 8:30 in the morning until midnight. During the night a light land breeze develops which moves down the mountain valleys toward the sea-coast at less than one mile an hour. In the summer and early fall, temperature inversion limits the vertical distribution of the atmospheric pollution and the local winds move the pollution over the area from the west during the day. If it does not escape through the mountain passes, the night breeze returns it—to be reinforced by the next day's contamination. The inversion layer is very resistant to turbulence and acts as a lid to hold pollution near the ground. The base of the inversion is often 500 feet above sea level. Visibility is greatly restricted at times

[1] The authors wish to express their gratitude for suggestions to Dr. Louis C. McCabe, and to Mr. Robert L. Chass, Chief Air Pollution Inspector, Air Pollution Control District, Los Angeles County, Los Angeles, California, and Mr. A. V. MacDonald, Executive Secretary of the Los Angeles Furniture Manufacturers Association for reading the manuscript.

of low inversion and eye and throat irritation are at a maximum. (It must be remembered that the Los Angeles area is the only large industrial area located in a semi-arid zone.)

This brief summary is given here to establish the difference of the Los Angeles area from large industrial areas elsewhere, a fact which must constantly be kept in mind during the course of this paper.

Local action and the law of nuisance were realized to be of little use in attacking this complex problem. (A comparison of areas over which various county enforcing agencies throughout the country have jurisdiction shows that Los Angeles County is the largest. The county consists of 4,083 square miles and is made up of 46 separate incorporated and unincorporated areas).

Recent Legislation

As a result in 1947, the California Legislature adopted certain amendments to the Health and Safety Code of the State *(5)* thus beginning a vast and new experiment in atmospheric pollution control which is without parallel at the present time with respect to the broadness of its approach—both in matters to be attacked and the areas to be covered. This statute is the first one of its kind passed in the United States by any state legislature, and what is being done in California, and more specifically in Los Angeles County, will undoubtedly form a precedent in many respects for similar action throughout the country and possibly throughout the world.

The new law allows any California county governing body (Board of Supervisors) to establish an "Air Pollution Control District" whenever it finds that the air within the county is "so polluted with air contaminants as to be injurious to health, or an obstruction to the free use of property, or offensive to the senses of a considerable number of persons, so as to interfere with the comfortable enjoyment of life and property." An air pollution control officer may be appointed to head up the district.

Certain prohibitions are set out in this law, any violation of which is a misdemeanor, and which may be enjoined in a civil action. The law declares that no one is to discharge into the atmosphere any "air contaminant" for a period or periods aggregating more than three minutes in any one hour which is as dark or darker in shade as that "designated as No. 2 on the Ringelmann Chart . . . or of such opacity as to obscure an observer's view to a degree equal to or greater than" does the smoke just described.

Now smoke is the only air contaminant which has any specific standard written into the California statute itself. With reference to other contaminants (and these include charred paper, dust, soot, grime, carbon, noxious acids, fumes, gases, odors, particulate matter or any combination of these), aside from the general prohibition against nuisances, the air pollution control board can set the amount to be emitted by adoption of rules and regulations.

In Los Angeles County an Air Pollution Control District has been created, and its rules and regulations state that no person may discharge into the atmosphere any particulate matter in excess of 0.40 grains per cubic foot at the point of discharge. Lead, zinc oxide and sulphur fumes are also curbed. Other limitations or standards may be expected in the future as the air pollution control board finds additional emissions which may pollute the air.

Enforcement

One of the methods of enforcing the law is through a system of operating permits. Any person building, erecting, altering, replacing, operating or using on or after February 1, 1948, any article, machine, equipment or other contrivance, the use of which may cause the issuance of air contaminants, must first obtain a permit for such operation *(6)*.

Furthermore, any person building, erecting, altering or replacing (if the cost is over $300.00) any article, machine, equipment or other contrivance, the use of which may cause the issuance of air contaminants must first file plans and specifications with the Air Pollution Control District and obtain authority to construct before starting work. Before authority to construct is granted, it must be shown that every item is so designed or constituted, or equipped with such air pollution control equipment, that with proper supervision and use it may be expected to operate without emitting air contaminants in violations of the law *(7)*.

A permit may be suspended or revoked, however, if any violations of law occur. Any-

one operating without a permit or contrary to its terms may be guilty of a misdemeanor. Furthermore, the air pollution control officer may request and must be given information by the applicant which the officer feels is necessary to have in granting a permit *(8)*.

If one is unhappy with a particular ruling of the air pollution control officer, he may go to a Hearing Board which is composed of two lawyers and one engineer. The Board may grant a variance or other relief from the general limits of the law as the facts warrant. Incidentally, it should be pointed out that the air pollution control officer does not, himself, permanently revoke a permit. Rather he must request the Hearing Board to do this.

Appeal may be had from an adverse ruling of the Hearing Board in the form of a trial *de novo* of the reasonableness and legality of the prior decisions on all issues of law, fact and opinion in the Superior Court.

Such then is the topographical and meteorological setting of the problem and the legal tools available for solving it. It is not likely that we can hope for a return of idyllic conditions of unpolluted atmosphere. The best we can probably do is, as stated in the California law, to "reduce air contaminants in order to safeguard life, health, property, and the public welfare and to make possible the comfortable enjoyment of life and property" *(9)*. And we must do this without destroying the huge investment in industry which supports the economy of the area.

Contribution of Wood Processing Industries to Atmospheric Pollution in the Area

The amount of wood waste in the Los Angeles area—in the form of wood shavings, sawdust and blocks—has been reliably estimated to be some 5000 tons daily. This wood waste represents at least 80 billion Btu! It is equivalent to the amount of refuse created by a population of two million people. Surveys of the furniture manufacturing and retail lumber industries in Los Angeles indicate that most of their wood waste is destroyed by incineration at the site.

In Los Angeles the problem of wood waste disposal is unique because the waste cannot be utilized, as in other areas, for heat and power. It must be destroyed, for in its unconverted state it has no commercial value. If we assume this latter condition to be true for our purposes here, it follows logically that our problem is to dispose of the waste in the most economical fashion compatible with the laws of California pertaining to atmospheric pollution, public nuisances and fire hazards.

Today we do not utilize the wood waste in this area for fuel primarily because there are no facilities to utilize this great release of heat. These facilities have not been made available because there has been no need for this heat. There are sufficient quantities of low cost fuel oil for the small need. Furthermore, the users of the heat are so wide-spread in point of plant location in the area that central heating systems are not economically feasible. And, the producers of the wood waste are so scattered about that collection of the waste to a central place is a difficult—although probably not insolvable—matter.

Due to the peculiar topography and meteorology, the minimal standards of emission which exist elsewhere are not adequate here to cope with the problem of air pollution posed by the combustion of this wood waste. When we have incomplete combustion, we observe that smoke, fly ash, aldehydes and possibly other contaminants escape into the atmosphere. When the smoke is too dense, the fly ash or particulate matter too heavy, or the aldehydes too concentrated, not only may the destruction of wood waste be violating the law, but it may actually be responsible for some of the lachrymating effect of the smog. Thus a fairly recent study indicated that some individuals are quite sensitive to aldehydes and seem to exhibit severe responses to nose and eye irritation, often with profuse nasal secretion and lachrymation *(10)*.

The problem, then, which will be the subject of the remainder of this paper is the disposal of this waste material as described above within the limitations as set out here.

The Disposal of Wood Waste by Incineration

Rather than allow the wood waste to pile up and occupy valuable space and create a fire hazard the simplest and cheapest method of disposal is by burning. In the past, burning was carried on in open, unenclosed spaces. Some-

times, to conform to fire regulations, an enclosed, single combustion chamber was used, but in no case was the amount of smoke or fly ash emitted into the atmosphere given any consideration.

At the outset we will do well to take note of the distinction between the incinerator and the boiler. A fundamental distinction can be made as to the purpose of each device. It is the purpose of the incinerator to destroy the material without the utilization of the heat released, whereas the purpose of the boiler is to utilize the material as a fuel to obtain steam or hot water. An incinerator can be converted into a waste-heat boiler if we choose to utilize the heat created.

Combustion and Combustion Products

In either case our concern is combustion, which may be defined simply as rapid, high temperature oxidation. Let us see what happens when wood waste burns. Below 500° F. volatiles are distilled off. Above 540° F. exothermic reactions take place and the distillation of the volatiles continues with the evolution of about six percent of the total available heat. Above 1100° F. volatile gases are ignited. This is true providing the woods are not too wet, since the evaporation of moisture absorbs about 1,000 Btu per pound of moisture present *(11)*.

With the exception of combustion of elementary carbon, oxidation reactions occur in the gas phase *(12)*. The combustion mechanism is that of rapid chain reaction. Chain reactions in the combustion of fuels are vastly complicated. The type and predominance of the various chain steps depend to some extent upon the type of fuel, but since the essential chemical ingredients of all fuels are carbon and hydrogen, the process of burning is controlled more by external factors such as concentrations, temperature, and the manner of mixing of the primary or secondary air supply, than by the difference of composition and other characteristcs of the fuel. Because of their complexity, neither qualitative nor quantitative knowledge of chain reactions in combustion is complete.

At the temperature of combustion, hydrocarbons, rapidly dissociate into free hydrocarbon radicals. The hydrocarbon radicals are liable to oxygen attack, and highly reactive, unstable oxygenated compounds or radicals are formed which have only transitory lives. Nevertheless, it is now generally accepted that only through successions of these active radicals are the carbon and hydrogen of fuels converted by complete combustion into carbon dioxide and water. Aldehydes, although likewise of transitory existence, are essential links in the combustion process.

Combustion, it is classicly stated, depends upon the "three Ts": temperature, time (of exposure in combustion chamber) and turbulence. These are all vital factors in efficient combustion. There must be sufficient time to ignite and burn the fuel completely; the temperature must be high enough to ignite and burn the fuel properly, and in order to burn the fuel completely, there must be sufficient turbulence in the furnace to insure thorough mixture of the gases, or some will escape without being burned *(13)*.

When these factors are in perfect relationship to each other, we should have smokeless burning—because we should have perfect and complete combustion. On the other hand, when they are not in harmonious relationship we have incomplete combustion which causes (1) smoke, creating a nuisance and adding to the smog; (2) eye irritants, such as aldehydes, alkyl-peroxides and other organic compounds; and (3) particulate matter (such as fly-ash and soot) which may create a local nuisance. Quite frequently, such incomplete combustion will result in violations of air pollution control laws.

In the single combustion chamber type of incinerator (variously called "silo" type or "enclosed bonfire") which is almost characteristic of the West Coast, we have no control, really, of any of these three Ts. We can attempt some control of turbulence, by the installation of air blowers, or air ports. But since the other two elements are not controlled we may still have incomplete combustion.

As a matter of theoretical consideration, even the single combustion chamber could be made to work under a system of careful feed and control. But it is not economical in the small plant where we have erratic feed in type and amount and where we have only superficial attention paid to the burning operation. The reason for the existence of this type of in-

cinerator at all is because it costs relatively little to build and the construction is simple. It is only the advent of strict laws which has caused manufacturers and users of such equipment to examine the principles upon which these incinerators are being utilized.

Recommendations Set Up to Aid Wood Using Industries

In order to help owners of incinerators to comply with air pollution control laws (and thus protect their investment in the single chamber type of incinerator), the Los Angeles Furniture Manufacturers Association, in conjunction with the Los Angeles Air Pollution Control District, has promulgated standing operating procedures to be applied in operating the silo-type incinerator. It will be seen that they simply seek to obtain the conditions which are ideal for complete combustion. Conscientious application of these rules, it is believed, will enable the operator to arrive at more complete combustion and thus stay within the legal limitations which have been established:

"*1.* The California Health and Safety Code prohibits emission of dense smoke for more than 3 minutes in any one hour. There are also strict limitations on emission of particulate matter and of fumes and gases. Any person who violates the state law or a Rule or Regulation of the Air Pollution Control District is guilty of a misdemeanor. This includes both the owner of the incinerator and the immediate operator.

"*2.* Basically, as high a temperature as possible, must be maintained at all times to insure complete combustion. This temperature should be at least 1200° Fahrenheit.

"*3.* Do not use the incinerator until enough waste material has been accumulated to warrant its use. This may mean burning the scrap or waste material some time after starting up the plant, or it may mean burning it only on alternate days.

"*4.* Incinerators are designed for a given quantity of combustibles. Should this quantity vary greatly, either black, white, or brown smoke will result.

"*5.* Generally speaking, when black smoke is emitted, there is insufficient air getting into the incinerator. If white or brown smoke is emitted, there is too much air. (Too much air has the effect of cooling down the fire below the temperature required for complete combustion.)

"*6.* Should the conditions in the plant change, corresponding adjustments to the incinerator should be made immediately. These changes usually mean adjusting the quantity of air getting into the incinerator, or throwing in additional scrap wood to help increase the temperature.

"*7.* There are three ways, at least, in which air can get into the incinerator:

(a) Through the charging door,
(b) Through the blower system,
(c) Through the air ports around the circumference of the incinerator.

"*8.* When the charging door is closed, and the incinerator is still emitting white or brown smoke, one of three things must be done immediately:

(a) Regulate the amount of air entering through the air ports,
(b) Increase the amount of material going into the incinerator,
(c) Or both.

"*9.* Never open the charging door when the blower system is on. Keeping the charging door open when the blower system is on, increases the speed with which the sawdust will leave the incinerator through the top of the screen. This will result in a heavy discharge of fly ash and a possible nuisance. It will also cool the fire quite rapidly to the point where smoke will appear.

"*10.* Use scrap lumber to good advantage especially during such periods as the lunch hour, the time prior to the starting up of the incinerator, and any other times in which the flow of material from the machine is at a low ebb.

"*11.* Should the practice of accumulating the material in the incinerator be followed, extreme caution should be taken to insure that there are no smoldering embers remaining. If there are, the embers and ashes should be scraped out of the incinerator or removed by some other means. Care should be exercised to prevent the material from piling up higher than one foot below discharge vent into incinerator.

"*12.* Do not burn so much material at one time that the flames reach the screen of the incinerator.

"*13.* It is entirely possible to burn such materials as oily rags and material containing paints and lacquers providing these items are thrown into the incinerator in *very small* quantities and *only when extremely high temperatures exist.*

"*14.* The incinerator, even though there are no moving parts, should be kept in good repair. This includes plugging all leaks in the blower system, plugging the leaks at the point where the material enters the incinerator, maintaining the devices for regulating the amount of air entering through the air ports, insuring close fit for the charging door, cleaning out the accumulated ash regularly, keeping the fire brick in good repair, and maintaining a clean and whole screen on top of the incinerator.

"*15.* Few of these rules of good operation of incinerators will operate automatically. Close surveillance must be kept on the burning operation and action must be taken quickly when a violation is discovered. Nor will the rules here given take care of an incinerator which is not in good repair nor will they take care of an incinerator which is not designed for the purpose for which it is used; but they will, if applied conscientiously, facilitate the use of the incinerator with a minimum of difficulty."

Multiple-Chamber Incinerators

Since the silo-type incinerator is so difficult to control, designers have turned to multiple chamber incinerators as a solution. By virtue of its construction, this type of incinerator will overcome several of the difficulties of the single chamber. For example, the immediate escape of hot gases is retarded more easily when there is more than one chamber.

We have already seen that maintenance of adequate temperatures is an important requirement to smokeless burning. In the multiple chamber incinerator, proper temperatures are easier to maintain because retaining and bridge walls become hot refractory surfaces which receive heat from the flame and transmit it to the colder portions of the burning mixture, thus increasing the rates of ignition and combustion. At proper temperatures, unburned gases have a chance to burn when mixed with the proper amount of air in the second chamber. We have already noted that in the single chamber incinerator, the gases can escape without burning.

Experience and study of ignition temperatures *(14)* indicate that 1200° F., especially in the secondary combustion chamber, is essential to smokeless burning. Design must be such that it always assures a sufficient supply of air to complete this combustion both in the primary (or furnace) and, most importantly, in the secondary chambers. Too little air or too much air, as we have seen, will result in smoke. Adequate air supply must be provided by maintenance of proper pressures and drafts at various points.

Auxiliary fuels, such as gas or oil, may be needed to give more adequate control of the temperature. Perhaps 90 per cent of multiple chamber incinerators have auxiliary heat in the form of gas burners. Such fuels may be introduced either into the primary or secondary chambers or into both of them.

Turbulence is easier to maintain in the multiple chamber incinerator. A bridge wall will force the air to change direction. Secondary air, if introduced at this point, will give a turbulent effect, and the added oxygen will serve to complete the combustion. Of course, the incinerator must be designed so heat velocity, as such, through the secondary chamber gives the gas carrying the fly ash time to let the particulate matter settle out. And the abrupt change in the direction of the gases caused by the several chambers will assist greatly in this settling out of the particulate matter.

Mechanical Devices Increase Incinerator Efficiency

Some mechanical devices are available for use with all incinerators. Thus turbulence may be maintained by using a mechanical blower. Fly ash nuisance may be attacked by the use of a water spray or filter. These add, of course, to the cost of construction of the incinerator.

Mechanical smoke indicators by themselves do not solve the problem of incomplete combustion. They serve only to act as a warning that smoke may be too dense. A smoke indicator is certainly of little value when the stack is in the open, for the emissions from the stack should be visible to whoever is responsible for

its effective and efficient operation. Indicators are of some value where the heat is being utilized, however, and in that case they can save money.

Operation Must Not Be Slighted

Although design is vitally important for the proper functioning of an incinerator, operating technique is perhaps even more important. No incinerator will work properly with improper operating procedure. For that matter, neither will a boiler operate correctly, if improperly handled.

There is an inclination, on the part of the user of the incinerator, because he earns nothing from the destruction of waste wood, to slough off the operation of his incinerator on an unskilled worker. But it is clear, as a result of existing legislation and present administration, that the task of incineration must be taken more seriously. The operating rules cited before certainly offer a starting place in education of management and employees towards cleaner and more efficient incinerator operation.

Good operation, too, will usually take care of such troublesome matters as sander dust and oily rags. Sander dust is a problem frequently encountered in the burning of wood waste. In the single chamber or silo-type incinerator, because we have so little control over time of exposure and air, the dust may go out the stack before it burns. But the multiple chamber by its nature overcomes this difficulty. As for the silo, there is probably no more effective solution than feeding the sander dust in with all other waste to be sure that it has a chance to be mixed with the waste and remain in the incinerator until it is completely burned. (We are not concerned here with sander dust which is so fine that it escapes from the cyclone before it gets to the incinerator).

In this connection, it is well to consider providing a system of uniform feed for the incinerator. This will help combustion, too. A method which may be used is to provide a storage bin for the waste, and to allow the waste to be fed into the incinerator by use of a conveyor belt or screw conveyor. This system can be used with single or multiple types of incinerators.

Burning of oily rags is merely a matter of temperature. When the fire is hot enough the rags may then be introduced and should burn smokelessly.

Outside of incineration, waste may be disposed of by open burning and by cut, fill and cover methods. The former method is now illegal in Los Angeles County, and the latter method is somewhat impracticable due to the bulk of the sawdust, blocks and shavings.

Conclusions

Users of incinerator equipment in the Los Angeles area have been forced to examine that equipment in the light of considerations other than merely the getting rid of troublesome waste. Law and regulation require that careful attention be given to burning or otherwise disposing of waste in a way which is not harmful to the community. Consequently, a duty has been thrown upon the manufacturers of incinerators to fill a definite need. We may indicate in a general way what events should take place to help solve the problems which have been created.

In the first place, it is clear that designers and manufacturers of incineration equipment will have to acquire more data about burning of wood waste. Many incinerators are designed from data taken from coal burning boilers, but experience has shown that such data cannot be used indiscriminately. We must know how much air is needed for complete combustion, where it should be introduced, the rate of air flow through the incinerator, as well as the optimum amount of refuse per square foot of grate area and proper temperatures. The degree of utilization of combustion space must be considered, too. Definite values for the amount of space which is required for combustion are hard to find in the literature because of the large number of variables which obscure the effect of each individual variable.

Secondly, incinerator operators must take seriously the task of learning what makes the incinerator tick and impress upon operating personnel that there are ways in which they can make the incinerator burn in compliance with the law.

Thirdly, we must continue to seek ways of utilizing the wood waste which is produced. This is not the place to go into that subject,

for the literature on this matter is already overwhelming.

Finally, some ways must be found to cut down on the amount of wood waste produced. It seems fantastic that the amount of wood waste we have mentioned at the outset should go up in flame and smoke, in just one area of this country.

The wood processor must pay for the lumber which dissipates itself as waste, he must pay transportation charges for hauling it to his mill, he must spend money in ways to produce the wood waste, and he has to pay again to dispose of it.

From the point of view of national conservation, then, as well as from the point of view of the individual, economical operation, intensive study and effort must be spent in seeking methods of operation which will utilize our lumber supply more effectively and with much less waste.

References

(1) Evelyn, John, 1661. Fumi-Fugium: or The Inconvenience of the Aer and Smoake of London Dissipated Together With Some Remedies humbly proposed To His Sacred Majestie and To the Parliament now Assembled. Reprinted, 1772. Reissued by Oxford University, London. (1930)

(2) Kennedy, Harold W. Legal Aspects of Air Pollution Control. Municipalities and the Law In Action. pp. 424–476. (1947)

(3) Rhyne, Charles S. and Van Meter, William G. City Smoke Control and Air Pollution Control Programs—Model Ordinance Annotated. 23 pp. Report No. 120, National Institute of Municipal Law Officers, Washington, D. C. (1947)

(4) Material concerning the Los Angeles basin is taken in great part from two addresses by Dr. Louis C. McCabe, Director, Los Angeles County Air Pollution, Control District. Refer also to Bee, Charles G. P. and Leopold, Luna B., Meteorological Factors Influencing Air Pollution in the Los Angeles Area. Trans. American Geophysical Union, Vol. 28, No. 2 (April, 1947). See also Poppendiek, H. F., Edinger, J. G., Greenfield, M. L., Hamming, W. J., and McEwen, L. H., A Report on An Atmospheric Pollution Investigation in the Los Angeles Basin, University of California at Los Angeles. (June, 1948)

(5) California Health and Safety Code, Division 20, Chapter 2.

(6) Rules and Regulations of the Air Pollution Control District, Regulation II, Rule 10.

(7) Rules and Regulations of the Air Pollution Control District, Regulation II, Rule 20.

(8) California Health and Safety Code, Division 20, Chapter 2, Section 24269.

(9) California Health and Safety Code, Division 20, Chapter 2, Section 24199 (d).

(10) Roth, Herman P. and Swenson, Engelbrekt A. Physiological Studies of Irritant Aspects of Atmospheric Pollution. School of Medicine, University of Southern California, Los Angeles, California. (1947)

(11) Steiner, K. 1946. Fuels and Fuel Burners. New York. p. 374.

(12) Griswold, John. 1946. Fuels, Combustion and Furnaces. New York. p. 181.

(13) Adapted from Harrington, Joseph. 1944. Practical Suggestions on the Elimination of Fuel Waste. Reprinted from National Engineer.

(14) Shindman, Louis. Gaseous Fuels. American Gas Association. New York. (1948)

FOREST PRODUCTS RESEARCH SOCIETY

Prediction of Pulp Mill Pollution*

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This paper describes procedures for calculating the effects of waste sulfite liquor on biochemical oxygen demand in waters of known characteristics. It describes how such calculations were used to predict pollution to be produced by a proposed pulp mill and to provide for controlling such pollution by suitable plant design and operation. The predictions have been subsequently proven by actual operation of the mill in question.

Introduction

DURING the past generation there has been continuous disagreement between industry and fisheries conservationists over the pollution of natural waterways by pulp mill sewage. Both agree that the waste liquors can pollute the waters and kill the fish. Pulp mill owners argue that the loss of a "few fish" is inconsequential compared to the benefits from a large development employing hundreds of men. The conservationists point out that the fisheries are an industry in themselves, comparable in magnitude to the pulp industry.

Regardless of the rights or wrongs in individual cases, it is poor social economy to develop one industry at the expense of another. Such a course leads to litigation, subsidies, restrictions, and other parasitical expenses, which can, and frequently do, absorb the profit margin in desirable industrial development.

Therefore it is the responsibility of scientists and engineers to anticipate the problems, and adjust the undertakings so that each resource may be developed to the highest economic levels without depredations on neighboring industries or persons. With this background the avoidance of pulp mill pollution becomes an economic and social problem, as well as a technical undertaking.

Heretofore, the effect of industrial pollution was not realized until it was accomplished, and was almost invariably followed by attempts at remedial measures which are generally expensive and ineffectual. Recently it has been possible to establish a measure of pollution, and in the case of the pulp industry, to predict the state likely to result from a given development. Obviously it is most efficient to predict the degree of pollution, and adjust the development in the planning stage. Even in the cases where pollution already exists it is advantageous to measure its degree, and be in a position to estimate the corrective measures required.

Fisheries

Salmon, herring, and halibut constitute the principal Canadian fisheries on the Pacific Coast. Halibut being an offshore fishery is not affected by industrial pollution. Herring come to inshore waters to spawn and there is no evidence as yet that they have been adversely affected, but the salmon are very vulnerable.

Salmon spawn in streams, lakes, and rivers where the eggs and young remain for a period of a few months to a year or more. They go to sea, attain maturity, and return to the fresh water to spawn and die. Aside from the radioactive debris from Atomic bombs, there are no pollution factors likely to have an economic effect in the open sea. However pollution or obstruction of fresh waterways can be, and sometimes is, of principal economic importance.

Types of Pulp Mill Locations

In general pulp mills that discharge their waste into large seaways, where infinite dilution of the sewage is quickly attained, are not sources of economic pollution. Such instances are represented by the wood fiber plant on Howe Sound, British Columbia Pulp and Paper mill in Quatsino Sound, and the Powell River development on Georgia Strait.

A second type of economically inconsequential pollution is represented by the pulp mill at Ocean Falls, B. C., where the sewage is discharged into a small inlet that never had a fishery.

* Presented by title only.

The risk of pollution occurs when the pulp mill waste is discharged into a waterway where dilution is limited. Such cases are demonstrated by the developments in Gray's Harbor, and Oakland Bay, Wash.

Theory of Pollution

Regardless of the nature of the pollution, there must be some level at which it can be tolerated by the life in any environment. This implies that there are degrees of pollution, less than the critical level, which are tolerable. Therefore the degree of pollution (P) may be defined in a completely general sense by

$$P = \frac{\text{Pollution effects}}{\text{Limit of tolerance}} \quad \text{----------} (1)$$

where the effects and limits are expressed in comparable terms. Then the state is tolerable while the degree of pollution is one or less

$$P_{\text{tolerable}} \leqq 1$$

It remains to define and evaluate the terms of this equation in any given instance.

In the case of pulp mill pollution, it is the consensus of the literature that the only pollution effect of waste sulphite liquor that is of consequence, at dilutions of 500 parts per million or greater, is the biochemical oxygen demand (B.O.D.). Further, the maximum tolerable oxygen depletion is 60 percent of the oxygen solubility (DO). Then the limiting tolerable pollution would occur when

$$P = \frac{\text{B.O.D.}}{0.6(\text{DO})} = 1 \quad \text{----------} (2)$$

in a volume that was initially saturated with dissolved oxygen.

TABLE 1.—PRODUCTION CHARACTERISTICS OF THE PROPOSED PULP MILL

Rate of production (tons of pulp per day)	135
Waste sulphite liquor (digester liquor) (gallons U.S. per day)	308, 000
(cu. ft. per day)	41, 200
Mean rate of discharge (c.f.s.)	0.477
Density of digester liquor	1.048
Percent solids in solution	11–12
Wash water (gallons U.S. per day)	5, 650, 000
(cu. ft. per day)	755, 000
Miscellaneous water from the mill (U.S. gal. per day)	1, 500, 000
(cu. ft. per day)	200, 200
Total volume of sulphite sewage (digester liquor + wash water) (U.S. gal. per day)	5, 958, 000
(cu. ft. per day)	784, 000
Steady rate of discharge (c.f.s.)	9.1
Percent concentration of digester liquor in sewage (solids)	0.61
Density of sewage (Townsend) (equivalent to sea water of 1.7‰ Cl)	1.0062

The application of this equation may be simply illustrated in the prediction of the pollution likely to occur from a standard 135 ton sulphite pulp mill, discharging untreated waste sulphite liquor, along with all other mill water, into an adjacent river. The pertinent characteristics of such a mill are given in Table 1.

Biochemical Oxygen Demand, B.O.D.

Fig. 1 shows the calculated demand of waste sulphite liquor at a concentration of one part per million (0.01 of the demand at 100 p.p.m.) (B.O.D.)* derived from a study of the literature pertaining to pulp mills in the Northwest.

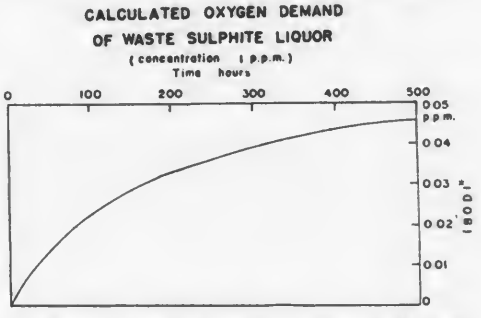

Fig. 1.—Calculated oxygen demand of waste sulphite liquor at a concentration of one part per million (0.01 of the demand at 100 parts per million). Biochemical oxygen demand (B.O.D.)* derived from a study of the literature pertaining to pulp mills in the Northwest.

Concentration of Waste Sulphite Liquor

If the waste sulphite liquor is mixed with all mill water and discharged at approximately the density of the river water, it will normally be uniformly distributed in the river water within a day's flow downstream. Therefore the concentration of waste sulphite liquor (N) may be estimated as the ratio of the mill discharge of waste sulphite liquor (Q_E) to the river discharge (Q)

$$N = \frac{Q_E}{Q} \times 10^6 \text{ p.p.m.} \quad \text{----------} (3)$$

Then the oxygen demand is

$$\text{B.O.D.} = N(\text{B.O.D.})^* \quad \text{----------} (4)$$

Oxygen Supply

In a natural waterway the dissolved oxygen concentration is usually less than the solubility. This may be expressed as

$$(1 - d)(\text{DO})$$

where d is the deficiency, or departure from saturation (DO).

The deficiency must be counted as part of the oxygen demand, since it is not available to the fish. Therefore the equation of pollution becomes

$$P = \frac{N(B.O.D.)^*}{(0.6 - d)\,(DO)} \qquad (5)$$

The solubility of oxygen (DO) in fresh and sea water is given in Table 2. The evaluation of the oxygen deficiency (d) implies that the normal concentration of oxygen in the unpolluted waterway is known, or can be estimated.

TABLE 2.—SOLUBILITY OF OXYGEN IN FRESH AND SEA WATER

(Whipple and Whipple, J.A.C.S. XXXIII, 1911)

Temperature °C	Chlorinity (Cl°/₀₀) of Sea Water					
	0 Fresh	4	8	12	16	20
	Oxygen solubility (p.p.m.)					
0	14.62	13.96	13.30	12.64	11.98	11.32
4	13.13	12.55	11.98	11.40	10.83	10.25
8	11.87	11.37	10.86	10.36	9.86	9.36
12	10.83	10.39	9.94	9.50	9.06	8.62
16	9.95	9.56	9.16	8.77	8.38	7.99
20	9.17	8.82	8.47	8.12	7.77	7.42
24	8.53	8.20	7.87	7.54	7.21	6.87
28	7.92	7.61	7.30	6.99	6.68	6.37

Age of Waste Sulphite Liquor

As shown in Fig. 1, time is required for the oxygen demand to develop. During this time the effluent is presumably being carried away from the pulp mill sewer by the circulation in the natural waterway. Consequently the greatest depletion of oxygen must occur at some point downstream from the mill site, at the distance associated with four or five days flow. Therefore it is necessary to evaluate the pollution at intervals from the sewer outfall, to determine the position, and degree of the maximum pollution (P_{max}).

Estimation of Pollution in a River

Example 1

Consider the 135 ton sulphite mill (Table 1) wasting its effluent in a river, whose minimum flow is 2270 cubic feet per second at a distance corresponding to 50 hours flow from the millsite.

Then in Equations 3 and 4

$$N = \frac{0.477}{2270} \times 10^6 = 210 \text{ p.p.m.}$$

$(B.O.D.)^*$ at 50 hours $= 0.0153$ p.p.m. (Fig. 1)

$$B.O.D. = 210 \times 0.0153 = 3.21 \text{ p.p.m.}$$

The normal oxygen concentration is 9.2 p.p.m. at a temperature of 59° F. when the solubility would be 10.1 p.p.m. (Table 2). Then degree of saturation is

$$\frac{9.2}{10.1} = 0.9$$

wherefore the deficiency

$$d = 1.0 - 0.9 = 0.1$$

from which the oxygen supply is

$$(0.6 - 0.1)\,(10.1) = 5.05$$

and Equation 5 becomes

$$P = \frac{3.21}{5.05} = 0.64$$

which is the degree of pollution to be anticipated at the specified discharge of the river, and distance from the millsite.

Size of River Required

Example 2

It is to be remarked that the unit $(B.O.D.)^*$ increases to a maximum of 0.0448 p.p.m. in about 500 hours from which it is possible to predict the minimum flow which would tolerate the pollution from the proposed mill.

Substituting the oxygen supply (5.05) for B.O.D. and setting $(B.O.D.)^* = 0.0448$ in Equation 4

$$N = \frac{5.05}{0.448} = 113$$

and setting this value of N in Equation 3, the critical level of river discharge is,

$$Q = \frac{0.477}{133} \times 10^6 = 4240 \text{ c.f.s.}$$

River Increases Downstream

Example 3

The discharge of most rivers increases downstream as the drainage area increases; wherefore the concentration of waste sulphite liquor decreases while the oxygen demand increases. Consequently a mill may be established on a river whose flow is less than the critical level at the millsite, if its discharge increases downstream sufficiently to provide an oxygen supply equal to the demand. Such an instance is illustrated in Fig. 2.

Fig. 2,a shows the plan of a hypothetical river whose discharge is assumed to be monitored at five stations covering the distance travelled by the water in the course of 20 days.

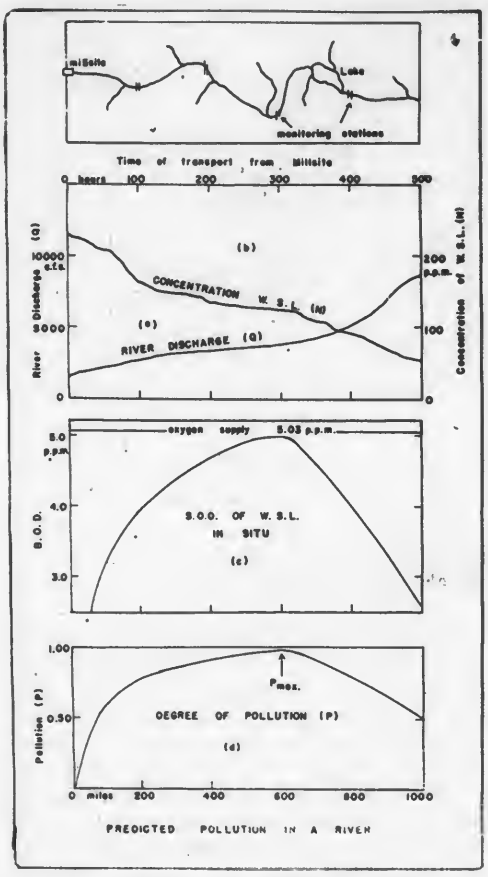

Fig. 2.—Relationship between waste sulphite liquor concentration, river discharge, biochemical oxygen demand, and degree of pollution for a hypothetical mill and river.

Fig. 2,b shows the river discharge referred to the left hand scale. This curve is interpolated between the observed points with reference to the approximate size of the tributory streams and their point of entry. The corresponding concentration of waste sulphite liquor is shown in the second curve (Fig. 2,b) referred to the right hand margin.

The biochemical oxygen demand, computed by Equation 5, is indexed to the left hand scale in Fig. 2,c and the observed oxygen supply $(0.6 - d)(DO)$ is referred to the right hand scale.

The degree of pollution (P) is shown in Fig. 2,d.

Evidently the degree of pollution will increase downstream to a maximum (P_{max}) which must not exceed 1.0 if the pollution is to be tolerable.

It remains to solve the relation of P_{max} to river level between the anticipated limits of discharge. Such a solution is shown in Fig. 3,

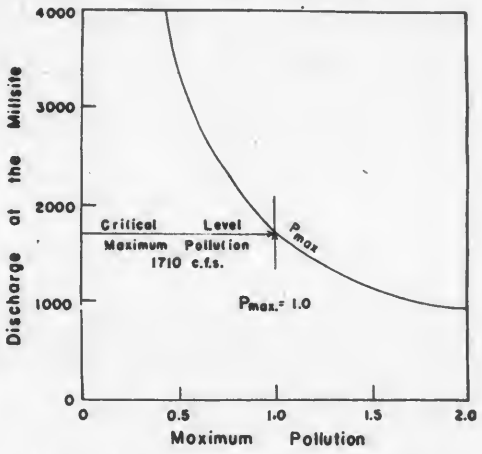

Fig. 3.—Relation of the degree of maximum pollution to the discharge of the river for the hypothetical mill and river shown in Fig. 2.

where it is indicated that the limiting tolerable degree of pollution may be expected when the river discharge is 1710 cubic feet per second at the millsite. The probability of this condition occurring may then be determined from run-off records.

Alberni Inlet

A more complex situation arises if the pulp mill discharges its effluent into a confined seaway such as an inlet or a bay. The water moves back and forth with the tide, progressing slowly seaward. The volume of water adjacent to the mill sewer is usually larger than most rivers, but the rate of flow is very much smaller, so that the effluent tends to accumulate in the vicinity. This may cause serious pollution if the millsite is associated with a commercial fishery.

Solution of this problem may be illustrated in the case of a proposed 135 ton sulphite pulp mill (Table 1) which was to discharge untreated waste into the head of Alberni Inlet, on the West coast of Vancouver Island.

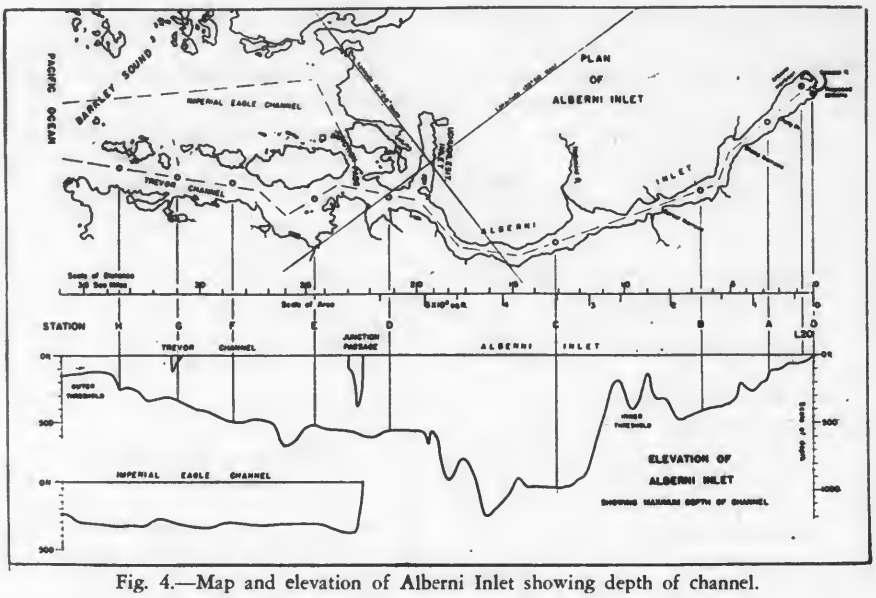

Fig. 4.—Map and elevation of Alberni Inlet showing depth of channel.

This inlet (Fig. 4) is a long narrow arm of the sea, having the typical fiord structure of the Canadian and Alaskan inlets. Over most of its length it is a two dimensional estuary system. Fresh water is continually being added to the surface from the Somass river (153 to 38,000 c.f.s.) at the head. The fresh water moves seaward, mixing with the underlying sea water enroute so that there is a longitudinal salinity gradient from head to mouth. In the region of the head of the inlet, the stream from the river diverges until it occupies the whole width, after which the transverse salinity gradient vanishes.

In vertical section (Fig. 5,a) the longitudinal salinity gradient is restricted to an upper zone defined by a point of inflexion in the salinity depth relation (Fig. 5,b). Below this inflexion there is a *middle zone* in which there is little or no longitudinal salinity gradient.

Without going into the exhaustive analysis given in the references[1, 2, 3] it is concluded that the fresh water moves seaward in the *upper zone* due to the isostatic head between the fresh water at the river mouth, and the saline water in the sea. During this progress the fresh water is mixed with sea water from the underlying *middle zone,* due to turbulence resulting from tidal velocities. Sea water enters the inlet only in the middle zone during the flooding tide, because it is more dense than the upper zone water, but leaves the inlet through both upper and middle zone, during the ebb tide phase. Consequently the movement is predominantly seaward in the upper zone, and towards the head in the middle zone.

All fresh water leaves the inlet by way of the upper zone, because any fresh water transferred downwards moves towards the head, adjacent to the boundary between the zones, and is preferentially subject to further mixing. Sea water transferred upwards is carried seaward to be mixed again.

The middle zone extends to the depth of the threshold (Figs. 4 and 5,a) which acts as a weir protecting the deep zone from all current producing forces, except frictional transfer from the middle zone. There is little or no circulation in this deep zone.

It follows that, if the waste sulphite liquor were mixed with all other waste mill water to a density approximately that of fresh water, and was discharged into the surface of the in-

[1] Tully, J. P., Oceanography of Alberni Inlet, Bul. Fish. Res. Bd. Ottawa, Canada.
[2] ——, Prediction of Pulp Mill Pollution in Alberni Inlet, Bul. Fish. Res. Bd. Ottawa, Canada.
[3] ——, Hollister, H. J., Fjarlie, R. L. I., and Anderson, W., A Hydraulic Model of Alberni Harbor, Bul. Fish. Res. Bd. Ottawa, Canada.

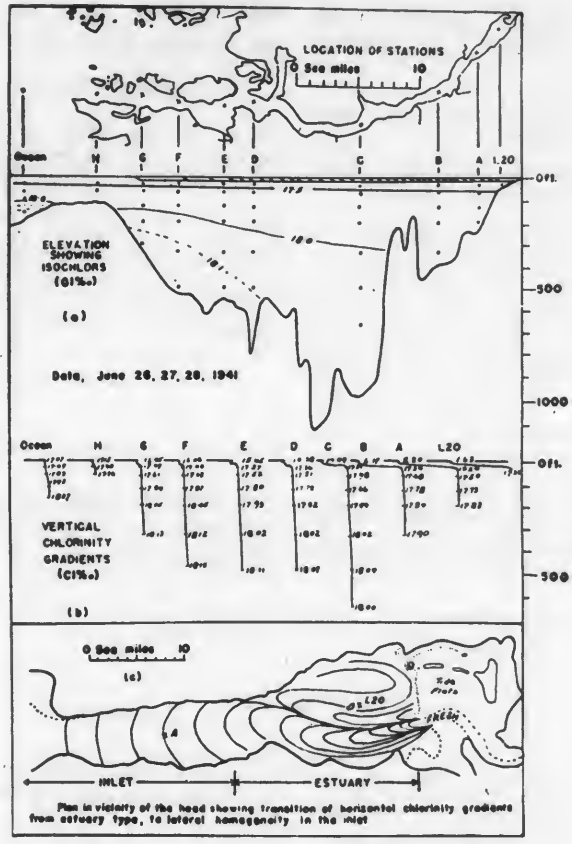
LOCATION OF STATIONS
0 Sea miles 10
Ocean N G F E D C B A L20
Off.
ELEVATION SHOWING ISOCHLORS (Cl‰)
(a)
Date, June 26, 27, 28, 1941
300
1000
VERTICAL CHLORINITY GRADIENTS (Cl‰)
(b)
0 Sea miles 10
(c)
INLET
ESTUARY
Plan in vicinity of the head showing transition of horizontal chlorinity gradients from estuary type, to lateral homogeneity in the inlet

Fig. 5.—Oceanographic properties of Alberni Inlet.

let, it would remain in the upper zone and move persistently seaward, leaving the deeper waters unpolluted.

If the concentrated blow pit liquor were discharged directly it would sink into the middle of deep zones. In the middle zone it would accumulate near the head until it was mixed into the upper zone. In the deep zone it would accumulate indefinitely but would be transferred upwards by diffusion, and eventually pollute all zones of the inlet. In the latter cases there would be no control of the accumulated effluent and if the pollution became intolerable, it would constitute a disaster that would destroy the fishery.

It was concluded that the first possibility should be accepted and the effluent confined to the upper zone, so that it would not accumulate. Then if the limit of tolerance were attained the pollutant could be controlled at the source, and in any case there would be unpolluted avenue for fish migration below the upper zone. This implied that the waste sulphite liquor should be mixed with all other mill water, and be discharged at the surface of the inlet.

Equation 5 is not directly applicable to a seaway because the transport is complicated by the reversing motion of the tide, and the effluent is diluted by sea water, as well as fresh. However it is evident that from any limited region a proportion (r) of the water is displaced seaward by a similar volume entering the region, during a tidal period (T = 24 hours 50 minutes).

Then during a tidal period only a specific part of the oxygen demand $(B.O.D.)_T$ can be satisfied, and the dissolved oxygen available to

supply this demand must be contained in the new water added to the region in the displacement process, hence

$$P = \frac{(B.O.D.)_T}{(0.6 - d)(DO)r} \text{ ----------} (6)$$

This equation was solved in Alberni inlet within very reasonable limits of accuracy.

Specific Biochemical Oxygen Demand

It is assumed that the limited region of the inlet is chosen such that the sewage is mixed to homogeneity before displacement occurs. Then the total concentration (N) of mill effluent in the region contains proportions of all ages. That is, at the end of the first tidal period there will be a concentration (Nr) of age 1 tide periods, $Nr(1 - r)$ of age 2 periods and $Nr(1 - r)^{n-1}$ of age n tide periods. Further, the specific biochemical oxygen demand during the present tide period, of the portion of age 1 period is $(\Delta B.O.D.)_1$, the demand of the portion of age 2 periods is $(\Delta B.O.D.)_2$, etc., so that the total oxygen demand in one tidal period (B.O.D.) is the sum of all these quantities.

$$[B.O.D.] = \sum_{1}^{\infty} [Nr(1 - r)^n (\Delta B.O.D.)_n]$$

which is representative if the region is small.

If the region is large enough to require an appreciable time for the transport of effluent through it, it must be assumed that the B.O.D. of the total discharge during the time of transit must be satisfied. Therefore a term is added,

$$Nr[B.O.D.]_o^m$$

where m signifies the time of transport in tidal periods. It may be recognized that on the average the effluent moves forward such that the number of tidal periods required to traverse the region is

$$m = T\frac{AZ}{AZr} = \frac{T}{r}$$

where A is the area of the region (Table 3), and Z is the mean depth of the upper zone (Fig. 5) in which the effluent is contained. This value of m may be substituted above.

TABLE 3.—CHARACTERISTICS OF ALBERNI INLET

	Interval			
	O–A	O–B	O–C	O–D
Length (feet)	15,600	37,980	79,580	128,780
Area (sq. feet) x 10^{-7}	8.00	16.30	34.80	64.90
Run-off Ratio (F)	1.00	1.173	1.55	1.95

Then a term describing the partial demand during the time of transport $m = T/r$ is to be subtracted.

$$\sum_{1}^{T/r} [Nr(1 - r)^n (\Delta B.O.D.)n]$$

because the oxygen demand in this time interval is represented by the second term.

Therefore the specific oxygen demand, to be supplied by the water entering the region in each tidal period is

$$\frac{(B.O.D.)_T}{Nr} = (B.O.D.)_o^{T/r} + \sum_{1}^{x} [(1 - r)^n (\Delta B.O.D.)n] - \sum_{1}^{T/r} [(1 - r)^n (\Delta B.O.D.)n] \text{ ----------} (7)$$

The solution of Equation 7, based on the rate of oxygen demand of Fig. 1, is shown in Fig. 6.

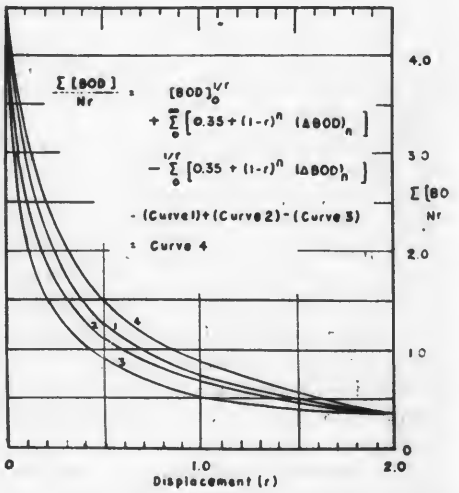

Fig. 6.—Oxygen demand of waste sulphite liquor during one tidal cycle in a region of displacement (r).

Substituting this value in Equation 6 the equation of pollution becomes

$$P = \frac{(B.O.D.)_T}{Nr} \cdot \frac{N}{(0.6 - d)\,(DO)} \quad (8)$$

which represents the average degree of pollution at the downstream limit of the region from which the effluent is about to be displaced.

Concentration (N) of Waste Sulphite Liquor

As shown in Equation 3 the concentration of waste sulphite liquor in the fresh water from the Somass river, may be expressed by the ratio of the discharge rates. Then the concentration of the river water in the inlet may be determined from the degree of dilution of the sea water.

Undiluted sea water in this location was defined by the salinity (Sb) occurring at 33 feet depth. It was observed that this base value was constant at this depth and represented the salinity of the sea water entering the inlet during the flood tide. The ratio of the observed salinity (So) at any point, to the base value (Sb) represents the proportion of sea water present, consequently the proportion of fresh water in the sample is

$$C = 1 - \frac{So}{Sb}$$

The ratio of land drainage in the continuing intervals (O-A, O-B etc.) to the discharge of the Somass river was evaluated in a factor F (Table 3). Then the concentration of water from this river at any station was

$$\frac{C}{F} = 1 - \frac{So}{Sb} \quad (9)$$

and the concentration of effluent is

$$N = \frac{Q_E}{Q} \cdot \frac{\bar{C}}{F} \quad (10)$$

where $\bar{C}$ is the mean proportion of fresh water in the limited region (O-A, O-B, etc.).

Displacement

It may be observed that mean sea level is constant, from which it is concluded that the inflow of water from all sources equals the outflow to the sea during a tidal day. Further, the distribution of salinity is recurrent, within small limits, at similar stages of the tide period, while the rate of land drainage, and the wind remains constant. Therefore it is concluded that a proportion of the fresh and sea water is displaced from the upper zone of the inlet to the sea in each tide cycle, by a like amount of fresh and sea water from their several sources. Further the process must apply quantitatively to any region of the inlet, otherwise the salinity structure would not remain constant.

It follows that the fresh water must move through the upper zone at the rate of land drainage, and the proportion (r) of water displaced seaward from any region of the inlet between the head (O) and any arbitrarily chosen cross section (A, B, C, etc.) may be evaluated as the ratio of the fresh water contributed by land drainage during a tide period $(\sum_0^T Q)$ to the volume of fresh water contained in the upper zone $(AZ\bar{C})$

$$r = \frac{\sum_0^T Q}{AZ\bar{C}} \quad (11)$$

where A is the area of the region (Table 3) and Z is the depth of the upper zone (Fig. 7).

Dissolved Oxygen Supply

During the critical period of the year (August, September) the dissolved oxygen concentration could be conservatively represented as 8.5 parts per million, which is about 0.9 of saturation. Then the available oxygen supply becomes

$$(0.6 - 0.1)\,(9.0) = 4.7 \text{ p.p.m.}$$

Characteristics of Alberni Inlet

It is evident from this reasoning that the displacement (r), the proportion of fresh water (C) the depth of the upper zone (Z) and the concentration (N) of waste sulphite liquor are all functions of the rate of land drainage in the particular situation. Oceanographic observations were made regularly at 5 representative stations (Fig. 4) from the time

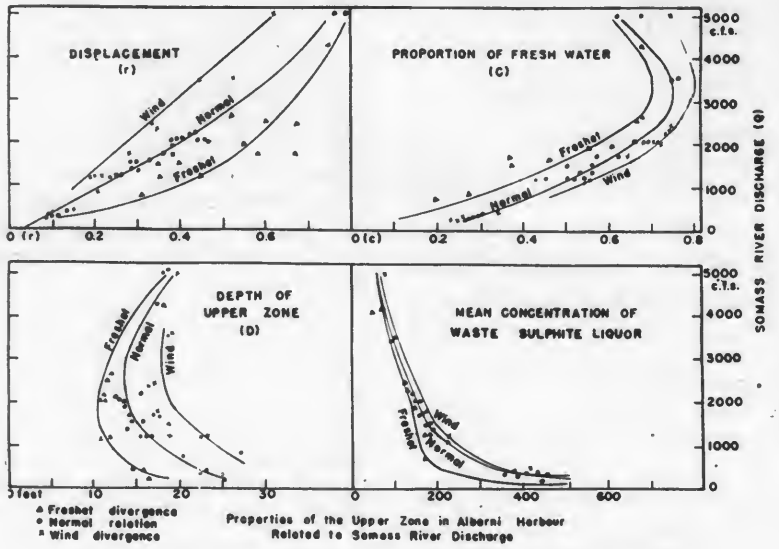

Fig. 7.—Properties of the upper zone in Alberni Harbor related to Somass River discharge.

of maximum river discharge in May to minimum in September. From these data the structure and mechanism of the seaway was defined in terms of the discharge of the principal river[1] as shown in Fig. 7.

It was observed that the relations were subject to the probability of there being a freshet which accelerated the displacement, and of adverse winds which retarded displacement.

The Degree of Pollution

From these data the degree of pollution at successive intervals (A, B, C, D) was computed in relation to river discharge as shown in Fig. 8.

Discussion

It was predicted that pollution would increase to seaward, attaining a maximum in about three miles from the millsite. In this interval the rate of oxygen demand (Δ B.O.D.) exceeds the rate of supply (0.5 (DO)r). Further to seaward the pollution would decrease with the rate of demand, and increase of oxygen supply.

The relation of maximum pollution to river discharge, shown in Fig. 8 indicates that, the critical relation, $P_{max} = 1$, would be reached when the Somass river discharge was between 1600 and 1800 c.f.s. When the river fell below

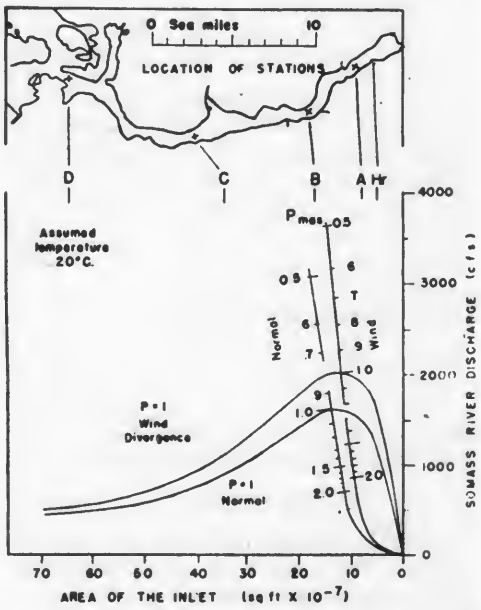

Fig. 8.—Calculated Alberni Inlet pollution from proposed sulphite pulp mill.

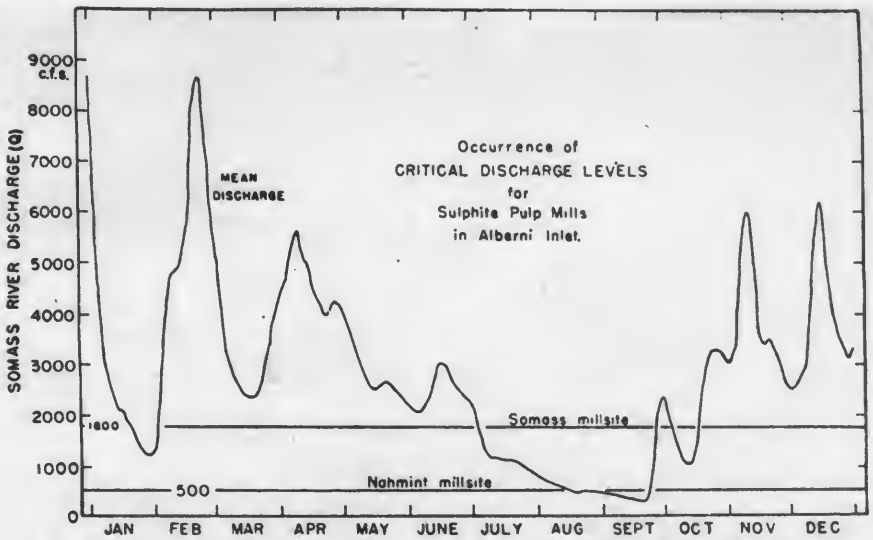

Fig. 9.—Occurrence of critical discharge levels for sulphite pulp mills in Alberni Inlet.

this level, as it does every summer (Fig. 9), the effluent would utilize all or part of the oxygen required for the fish. If the mill were located half way down the inlet, at Nahmint (Fig. 4) critical pollution would occur when the Somass river discharge was less than 500 cubic feet per second, and it would be necessary to limit operation for about one month every year.

It was shown that the restriction in operation could be obviated by storing water in the lakes at the head of the river, and releasing it so as to maintain land drainage above the critical level. Conversely the concentrated blow pit liquor could be stored in ponds during the summer, and released in the winter when the river was high.

The third possibility, proposed by the industry, was to build a sulphate mill from which the discharge of waste liquor would be so small that its oxygen demand could be tolerated at the lowest river levels, as shown in Table 4.

This sulphate mill (Fig. 10) has been built. The waste liquor is mixed with all other mill water and discharged into a pond, at the head of the inlet, where the waste fibers settle out. The overflow from this pond runs into Alberni harbor a short distance from the mouth of the Somass river.

Investigations to date have shown that the degree of pollution is within the predicted limits (Table 4). No deleterious pollution is anticipated.

TABLE 4.—ESTIMATED MAXIMUM POLLUTION IN THE UPPER ZONE OF ALBERNI INLET DURING THE LOW RIVER LEVELS, DUE TO SEWAGE FROM THE EXISTING (1948) SULPHATE PULP MILL

Discharge Somass R. (c.f.s.)	Concentration of sewage upper zone (p.p.m.)	Mean oxygen demand in upper zone (p.p.m.)	Dissolved oxygen concentration (p.p.m.)	Estimated degree of pollution (P max)[3]
153[1]	15,000	2.1	8.5	0.60
200	12,000	1.7	8.5	0.48
300	9,400	1.3	8.5	0.37
500	7,000	1.0[2]	8.5	0.28
700	6,200	0.9[2]	8.5	0.25
1000	5,100	0.7[2]	8.5	0.20

[1]153 cubic feet per second is the minimum recorded discharge of the Somass river.

[2]These small oxygen demands are within the natural limits of variation of dissolved oxygen, and would not be noticed in test of the water in Alberni Harbor.

[3]The degree of pollution (P) is the ratio of the oxygen demand of the pulp mill sewage to the dissolved oxygen available, in excess of the amount required for the fish. When the maximum pollution occurring anywhere in the inlet is 100 percent or less, there will be 5 parts per million, or more, of dissolved oxygen everywhere in the upper zone.

This solution does not take into account the natural aeration of the waters, which would occur during the flow. Such a process is imponderable, and should be regarded as a safety factor in the estimate.

No account has been taken of the problem arising from settling pulp fibers because the bottom of Alberni Inlet does not contribute to a commercial fishery. However the pond shown in Fig. 10 effectively removes the fibers, and

Fig. 10.—View of Bloedel, Stewart and Welch pulp mill at the head of Alberni Inlet, showing: A, pulp mill; B, sewer outlet; C, settling pond; D, overflow to log pond; and G, Somass River mouth.

could be adapted to other undertakings, where fibers are deleterious.

This solution proves a criterion for the limit of pulp mill development in Alberni Inlet. It is shown (Table 4) that 60 percent of the available oxygen will be required during the period of extreme minimum river flow. Consequently the expansion of this mill, or the establishment of another mill is restricted to the utilization of the remaining 40 percent.

At the time the problem was proposed, it was suggested that the pulp mill was of greater industrial value than the fishery of Alberni Inlet and should be permitted, even if the fishery were lost. Although this may be true, acceptance of the proposition would have provided precedent for unrestricted pollution in many other coastal seaways, which would probably be disasterous to the fisheries. The precedent illustrated here, of predicting the probable state of pollution and adapting the pulp mill to the situation may well ensure the survival of the salmon fishery.

Besides this, the present mill has all the assurance possible that it will not be subject to the litigation, restrictions, and subsidies which could have resulted if the originally proposed sulphite mill had been built.

It is pleasant to acknowledge the interest, and frequent assistance of Bloedel, Stewart, and Welch Ltd., while this research was in progress, to remark on their efficient implementation of the results, and their continued willingness to make adjustments as required.

In a situation where fish mortality indicates that pollution is excessive, it is advantageous to assess the degree, in order to estimate the extent and nature of corrective measures that are

required. In such a case the dissolved oxygen supply may be estimated at some point in the unpolluted portion of the system which may be assumed to be representative of the polluted reach, and substituted in Equation 5 or 8. The subsequent development of the prediction is identical with that illustrated.

The application of these principles to other forms of pollution is obvious. A measure of the principle pollution effect, and the limit of tolerance, in similar terms is substituted in Equation 1, and a solution developed similarly to these examples.

Conclusions

This research has established a quantitative measure of pollution, defined the tolerable limits, and shown how they may be evaluated either before or after pollution occurs in an inlet or river. It has created a precedent for the prediction of the probable degree of pollution from an industrial development, which in turn permitted adjustments to be made before the fishery was damaged.

The research is reviewed in detail in three papers which are to be published as a Bulletin of the Fisheries Research Board of Canada, Ottawa.

Chemical Composition of Ponderosa and Sugar Pine Barks[1*]

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This article summarizes the findings on the chemical analyses of the bark from ponderosa pine (*Pinus ponderosa* Laws.) and from sugar pine (*Pinus lambertiana* Dougl.). Bark of the ponderosa pine was found to contain 23.2 to 28.7 percent extractives, with the highest yield obtained from the bark at the bottom of the oldest trees. Tannin content ranged between 5.6 and 11.4 percent and appears to have possibilities for commercial extraction and utilization. Other extractives include a lignocerate wax, a phenolic-fatty acid complex, and a flavonol yellow coloring matter. There are at least two types of materials in the bark which appear as "lignin," and these are significantly different from wood lignins. Chemically these "lignin" components are similar to those found in redwood bark. The sugar pine bark contained approximately 21 to 22 percent of extractives. The tannin content ranged between 4.9 and 7.1 percent and the wax content between 2.2 and 3.1 percent. The major extractive was a reddish-brown phlobaphene; the minor extractives were lignoceric acid and an alcohol that sublimed above 305° C.

Introduction

THE Oregon Forest Products Laboratory has been engaged for some time in studies on the utilization of Douglas fir bark *(2, 4, 5, 6, 8)*. Recently, the Western Pine Association suggested the desirability of exploring the utilization of the bark from commercial species of the western pines. An examination of the literature has revealed that there are no previous reports on the chemical analysis of the bark from these pines. This article summarizes the findings on the chemical analyses of the bark from ponderosa pine (*Pinus ponderosa* Laws.) and from sugar pine (*Pinus lambertiana* Dougl.).

PART I. PONDEROSA PINE (*Pinus ponderosa* Laws.)

The ponderosa pine bark used in this work was collected in June 1948 from sawlogs in a commercial logging operation just north of Sisters, Oregon. All of the trees sampled were felled within 1 month previous to the time of the collection.

Samples were taken separately from the bottom (2-foot height), middle (32-foot height), and top (62-foot height) sections of five trees in each of the three age groups shown in Table 1. In all, 15 trees were sampled and, from the 45 samples of bark, nine composite samples were prepared for analysis. This gave a bottom, middle, and top composite sample for each age group. The bark of ponderosa pine is relatively thin; thus, the bark from the top of the trees had a high proportion of inner bark, whereas the bark samples from the bottom sections had little inner bark. The data recorded at the time of sampling are summarized in Table 1.

The bark of this species is scaly, nonfibrous, and has a characteristic yellow color. An anatomical examination indicated the presence of thin-walled parenchyma cells, cork cells, and sieve tubes. After collection, the samples were passed through a Greundler–Peerless hammer mill-shredder and air-dried to a moisture content of about 10 percent. Subsequently, they were ground in a Wiley mill to the appropriate fineness for analysis. The hammer mill-shredder reduced the moist bark to amorphous particles and a fine powder; no well-defined structural elements were distinguishable in the shredded bark. This bark does not contain cork of the nature found in the barks of Douglas fir

* Presented by title only.

[1] A joint project of the Oregon Forest Products Laboratory, State Board of Forestry, and School of Forestry, cooperating, Corvallis, Oregon and the Department of Chemistry, School of Science, Oregon State College, Corvallis, Oregon.

TABLE 1.—COLLECTION DATA ON PONDEROSA PINE BARK SAMPLES

Age group	Tree	Bottom Section (2-foot height)		Middle Section (32-foot height)		Top Section (62-foot height)	
		Dia. outside bark	Dia. inside bark	Dia. outside bark	Dia. inside bark	Dia. outside bark	Dia. inside bark
Years		In.	In.	In.	In.	In.	In.
150 to 200	1	27.5	23.5	20	18	14	13
	2	25	23	16	15	11	10.5
	3	24	22.5	15.5	15	9	8.5
	4	27	24	19.5	17	13	11.75
	5	24	22.5	18	17	12.5	12.0
200 to 250	6	32	29	22.5	20.75	16	15.5
	7	29	27	20	19	13.5	13
	8	26	25	20.5	19.25	14	13.5
	9	26	23	16	15	13	12
	10	41	36.5	25	23.5	13	12
250 to 300	11	42	39	27.25	24.75	15.5	13.5
	12	37	34	28	26.5	19.25	17.75
	13	33	30.75	22.5	21.5	14	13
	14	34.5	32.0	22	21	14	13
	15	43	41	32.25	31	23	22

(*Pseudotsuga taxifolia* Britt.) and the cork oak (*Quercus suber* L.).

Tannin Analysis

For the tannin content determination, the samples were extracted in the tannin extraction apparatus recommended by the American Leather Chemists' Association, and the extracts were then analyzed precisely in accordance with the official methods of that Association *(1)*. The data are given in Table 2.

It is evident from these data that the largest amount of tannin occurs in the bark at the bottom of ponderosa pine trees, particularly the older trees. This is the reverse of the tannin distribution found in the bark of Douglas-fir trees *(2)*. Tannin comprised approximately one-half of the soluble solid material leached from the bark with water under the conditions of the tannin extraction. The tannin content of the bark ranged between 5.6 and 11.4 percent, which is less than that found for Douglas fir bark, but still high enough to warrant further investigation.

A high sugar content is a striking characteristic of ponderosa pine tannin extracts; this is more than 10 times that found present in Douglas fir bark tannin extracts *(2)*. A certain amount of sugar in tan liquors is necessary for the proper curing of hides in commercial tanning processes. The tannin extract was used to tan sheepskin skivers. The tanned skivers had a light brown color, which indicated that the tannin possessed good leather-making qualities.

Ponderosa Pine Bark Extractives

The analytical results for ethyl ether, acetone, and hot-water solubilities, determined consecutively in that order, are shown in Table 3. These findings indicate that ponderosa pine bark is relatively rich in extractives; the total of the three extractives ranged between 23.2 and 28.7 percent. The highest yield of extractives was contained in the bark from the bottom of old trees. In this species, the ethyl-ether extractive was found to consist of a wax, m.p. 56° to 58° C., a phenolic-fatty acid complex,

TABLE 2.—ANALYSIS OF TANNIN EXTRACTS FROM PONDEROSA PINE BARK

(Percentages based on oven-dry weight of bark)

Age group	Sample	Total solids	Soluble solids	Insoluble	Tannin	Non-tannin	pH	Acid, as acetic	Reducing sugar	Total sugar after hydrolysis
Years		Percent	Percent	Percent	Percent	Percent		Percent	Percent	Percent
150 to 200	Bottom	16.2	13.9	2.3	7.7	6.2	3.4	0.016	2.61	2.88
	Middle	14.1	12.9	1.2	5.7	7.2	3.6	.012	3.02	3.11
	Top	16.9	14.9	2.0	6.5	8.4	3.7	.011	3.14	4.55
200 to 250	Bottom	20.2	17.8	2.4	10.4	7.4	3.5	.027	2.86	4.33
	Middle	16.3	14.5	1.8	5.6	8.9	3.8	.024	2.56	3.90
	Top	16.1	13.8	2.3	5.7	8.1	4.0	.020	3.18	4.32
250 to 300	Bottom	23.1	19.5	3.6	11.4	8.1	4.0	.020	5.60	6.16
	Middle	18.0	16.4	1.6	7.1	9.3	4.1	.018	2.22	2.77
	Top	17.9	16.1	1.8	7.0	9.1	4.1	.018	1.52	2.18

TABLE 3.—EXTRACTIVE CONTENT OF PONDEROSA PINE BARK

(Percent of oven-dry weight of the unextracted bark)

Age group	Sample	Moisture	Ethyl ether solubles	Acetone solubles	Water solubles	Total of three extractives
Years		Percent	Percent	Percent	Percent	Percent
150 to 200	Bottom	9.90	6.06	6.10	11.05	23.21
	Middle	9.76	5.47	5.47	12.94	23.73
	Top	9.25	6.54	6.54	13.15	25.84
200 to 250	Bottom	9.78	6.44	8.24	12.30	26.98
	Middle	9.32	5.13	4.67	12.42	23.22
	Top	9.68	6.17	5.58	12.20	23.95
250 to 300	Bottom	10.25	8.13	8.84	11.72	28.69
	Middle	9.64	6.11	5.78	11.89	23.78
	Top	9.05	7.33	6.59	13.20	27.12

and a yellow crystalline flavonol, in yields of 4.6, 1.7, and 1.4 percent respectively.

The flavonol, which is the substance that gives ponderosa pine bark its characteristic yellow color, was soluble in alcohol, and acetone, slightly soluble in water, benzene, and chloroform, and insoluble in petroleum ether. It gave a dark green color to ferric chloride and sodium hydroxide solutions; whereas, with zinc and hydrochloric acid it gave an orange-red color. It melted with decomposition at 305° C. and the penta-acetate derivative (40.7 percent acetyl groups) melted at 237° to 239° C. Methoxyl groups were absent.

The wax was found to consist of 42.1 percent of free behenic and lignoceric acids and 57.9 percent of neutral products. The latter, after saponification, gave 51.2 percent of similar fatty acids combined as the ester, and 48.8 percent of unsaponifiable matter.

The phenolic-fatty acid complex was soluble in benzene, but insoluble in petroleum ether. Saponification with alkalies gave a phlobaphene-like product and a fatty acid mixture.

Extractive-Free Ponderosa Pine Bark

Analyses of the bark residue after extraction with alcohol-benzene, ethanol, and hot water are shown in Table 4. The sum of the lignin, chlorite holocellulose, and ash residue accounted for 98.0 percent of the extractive-free bark.

Approximately one-half of the extractive-free bark residue is a non-cellulosic material determined as "lignin" in the usual lignin determination procedure. The other half is cellulosic in nature. Because the greater portion of the so-called lignin in the bark is tenaciously bound to the cellulose, chlorination procedures for the isolation of the cellulose were found not applicable. The ethanolamine holocellulose and the Cross and Bevan cellulose procedures gave products that retained over 30 percent lignin. Delignifaction with sodium chlorite in acetic acid solution *(3, 9)* gave a white residue that still contained 4 to 6 percent of lignin. Delignifaction beyond this limit led to marked loss of cellulosic material. It appears that the use of sodium chlorite for the isolation of cellulose from barks has not been tried previously.

TABLE 4.—ANALYSIS OF EXTRACTIVE-FREE PONDEROSA PINE BARK

(Percent of oven-dry weight of extracted bark)

Constituent	Percent
Ash	0.42
"Lignin", insoluble in 72% H_2SO_4	51.60
Chlorite holocellulose[1]	46.30
Pentosan	9.94
Methoxyl group	3.29
Acetyl group	0.76
Methoxyl in "Lignin"[2]	5.36
1% NaOH soluble	43.60

[1] Corrected for residual lignin.
[2] The methoxyl in "lignin" is based on the oven-dry weight of "lignin".

The quantitative procedure that was finally used for the determination of the cellulose is as follows:

A 3-gram sample of the extracted bark was weighed accurately on the analytical balance in duplicate and transferred to a 250-ml. Erlenmeyer flask. To the contents were added 160 ml. of distilled water, ten drops of glacial acetic acid, and 1.5 g. of sodium chlorite. The flask was sealed loosely by placing a 25-ml. Erlenmeyer flask in the neck and then heated in a hood at 70° to 80° C. for 30 minutes. At the end of this period, or when the chlorine dioxide fumes were no longer discharged, 10 drops of glacial acetic were added followed by an additional 1.5 g. of sodium chlorite. The suspension was thoroughly mixed and the heat-

TABLE 5.—ACTION OF CHLORINE DIOXIDE ON EXTRACTED PONDEROSA PINE BARK

Sample No.	Weight	Additions of $NaClO_2$	Time at room temp.	Holocellulose	Lignin	Holocellulose corrected for lignin
	Grams	No.	Hours	Percent	Percent	Percent
1	5.0	5	8	52.6	11.7	46.5
2	5.0	8	48	35.0	2.1	34.2
3	5.0	6	60	51.3	5.2	48.7
4	3.0	6	36	45.5	4.8	43.3
5	5.0	6	48	50.4	7.0	46.8
6	3.0	6	36	50.3	5.5	47.8
7	3.0	6	24	47.6	4.4	45.5
8	3.0	6	36	47.4	6.4	44.4

ing continued at 70° to 80° C. Six more additions of glacial acetic acid and sodium chlorite were made at one-half to 1-hour intervals over a period of approximately 4 hours. As the rate of chlorine dioxide consumption decreased, the later additions were made at 1-hour intervals. After the sixth addition of sodium chlorite, the flask was heated for 1 hour and then allowed to stand for 24 hours at room temperature. At the end of this period, the solution was filtered with suction through a tared, fritted-glass crucible. The cellulose was first washed thoroughly with water and then with acetone, air-dried to remove the excess of solvent, dried in an oven at 105° C. for 2 hours, cooled in a stoppered weighing bottle in a desiccator over concentrated sulfuric acid, and weighed.

This treatment gave a white product that still retained about five percent of lignin. A correction was made for this residual lignin in calculating the yield of cellulose in the bark. Data on the isolation of the cellulose that led to the adoption of the foregoing procedure are shown in Table 5.

Nature of the "Lignin" Fraction

The "lignin" in ponderosa pine bark was found to be a mixture of at least two substances, neither of which had the properties of lignin isolated from wood. Preliminary studies on the material isolated by the 72-percent H_2SO_4 lignin procedure revealed that it had a methoxyl content of 5.41 percent. About one-third was soluble in either hot 1-percent or hot 10-percent-caustic solution, and a portion was readily soluble in acetone, alcohol, or dioxane. The alkali soluble portion contained only 1.52 percent methoxyl groups, and the alkali insoluble portion, 7.67 percent methoxyl groups.

Direct extraction with hot 1-percent sodium hydroxide solution removed 43.60 percent of the extractive-free bark residue. Upon acidification of the caustic solution with dilute hydrochloric acid, a brown amorphous phenolic acid was precipitated (Fig. 1). This was recovered by centrifuging, washing with water, dissolving in a minimum of acetone, and then reprecipitating with benzene. As the excess hydrochloric acid was removed, the material formed

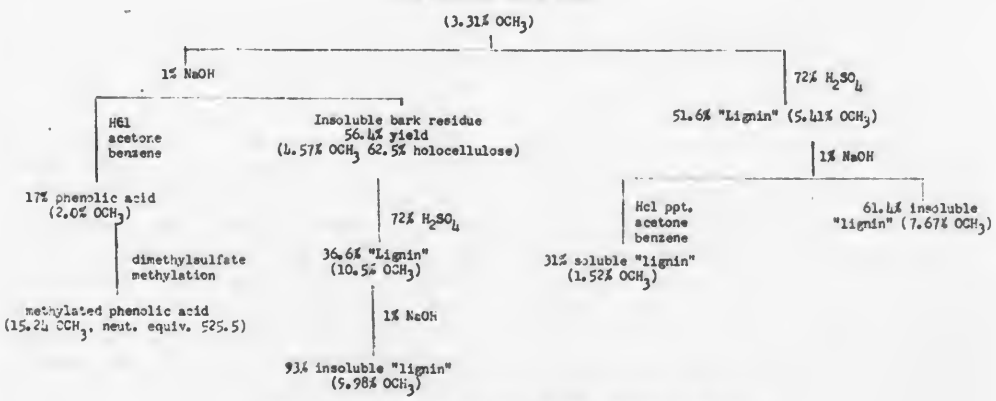

Figure 1. FRACTIONATION OF EXTRACTIVE-FREE PONDEROSA PINE BARK

a colloidal solution. The low yield of 17 percent resulted from incomplete precipitation and the difficulty in handling the product. It contained 2.0 percent methoxyl groups; whereas, complete methylation with dimethyl sulfate in sodium hydroxide solution gave a light brown product containing 15.24 percent methoxyl groups. The methylated product was soluble in dilute base and had a neutralization equivalent of 525.5. The bark residue that was insoluble in sodium-hydroxide solution amounted to 56.4 percent, contained 4.57 percent methoxyl groups, 36.6 percent 72-percent H_2SO_4 "lignin," and 62.5 percent chlorite holocellulose. "Lignin" plus holocellulose accounted for 99.1 percent of the alkali extracted bark residue. This "lignin" was insoluble in methanol, acetone, ethyl ether, and benzene, and had a methoxyl group content of 10.57 percent. Dioxane dissolved 31.8 percent and hot 1-percent sodium hydroxide only 7 percent of this alkali insoluble "lignin;" the alkali insoluble fraction contained 9.98 percent methoxyl groups. The higher methoxyl content of this alkali insoluble "lignin" indicates less contamination with the low methoxyl acid product. Apparently, 72-percent sulfuric acid renders the low methoxyl product less soluble in dilute alkalies.

Discussion

The tannin and wax in the bark from old ponderosa pine trees appear to have possibilities for commercial extraction and utilization. In this connection an integrated operation appears desirable. In addition certain of the naturally occurring flavonols have been shown to possess biological activity and medicinal value. Therefore, the extractives from ponderosa pine bark have been made the subject of further research.

The cellulose in ponderosa pine bark appears to be combined with lignin by a linkage which is resistant to splitting by chlorination procedures. Apparently, there are at least two types of materials in the bark which appear by analysis as lignin, and these are significantly different from wood lignins. One of them, the product dissolving in one percent sodium-hydroxide solution is present in large amount. It is soluble in acetone, contains little methoxyl, but significant percentages of free carboxyl and hydroxyl groups. The second is a product insoluble in acetone, methanol, and dilute alkaline solutions and has only about two-thirds methoxyl groups present in lignins from softwoods. From a chemical standpoint, ponderosa pine bark has "lignin" components very similar to those found in redwood bark *(7)*. The alkali-soluble matter in the latter bark is finding use as a dispersant.

PART II. SUGAR PINE BARK

(Pinus lambertiana Dougl.)

The sugar pine bark used in this work was collected in August 1948 from trees growing at an elevation of about 4500 feet in the Rogue River National Forest 15 miles north of Butte Falls, Oregon. Samples of bark were taken separately from the butt, middle, and top logs of five trees from 5½ to 6½ feet in diameter, which were recently felled in a commercial logging operation. Samples from smaller and younger trees were not available. The dense reddish-brown bark was 3 to 4 in. thick on the bottom logs and roughly 2 in. thick on the top logs. Examination of thin bark sections under the microscope showed the presence of typical thin-walled parenchyma cells, cork cells, and sieve tubes. It appeared non-fibrous in structure. The "cork" consisted of thin, hard, dark-colored particles, having little resemblance to the cork of Douglas fir bark or that of the cork oak.

After the bark samples were passed through a Greundler–Peerless hammer mill-shredder and air-drying to a moisture content of roughly 10 percent, they were further ground in a Wiley mill. Grinding in the hammer mill reduced the bark to amorphous particles and a fine dust; no well-defined structural elements, such as fiber or typical cork particles, were distinguishable.

The analytical results for ethyl ether, 95-percent ethanol, and hot-water solubles, determined consecutively in that order, are shown in Table 6. Tannin analyses, made by the official hide powder procedure of the American Leather Chemists Association, are given in Table 7.

The analyses indicate that sugar pine bark is relatively low in total wax and resin content (2.2 to 3.1 percent). Tannin content varied from 7.1 percent at the bottom of the trees to

TABLE 6.—EXTRACTIVE CONTENT OF SUGAR PINE BARK

(Percent of the oven-dry weight of unextracted bark)

Material	Bottom bark (2-ft. height)	Middle bark (48-ft. height)	Top bark (110-ft. height)
	Percent	Percent	Percent
Ethyl ether soluble	3.11	2.27	2.21
95% ethanol soluble	15.56	14.86	15.27
Hot-water soluble	2.32	4.80	4.00
Total of three extractives	20.99	21.93	21.48

TABLE 7.—TANNIN CONTENT OF SUGAR PINE BARK

(Percent of oven-dry weight of bark)

Material	Bottom logs	Middle logs	Top logs
	Percent	Percent	Percent
Tannin	7.1	4.9	5.6
Total solids	12.3	12.0	13.5
Soluble solids	10.4	10.3	11.0
Insoluble solids	1.9	1.7	2.5
Nontannin	3.3	5.4	5.4
Ratio tannin to soluble solids	68.2	47.5	50.9

4.9 percent at the middle and 5.6 percent at the top. The difference between the tannin content and the total ethanol soluble is representative of the phlobaphene content of this bark.

The ethyl ether extract from the bark from the bottom logs was a brown, partially crystalline solid; the chief components were a white crystalline alcohol which sublimed above 305° C. and a white crystalline fatty acid (m.p. 72° C.) that was similar to natural lignoceric acid. The crystalline alcohol was relatively insoluble in petroleum ether, ethanol, chloroform, and alkalies, but it was soluble in ethyl ether and hot benzene. After drying in the oven at 105° C., the ether extract formed a brown, hard, glossy resin.

An acetate derivative formed from the alcohol by refluxing with acetic anhydride and anhydrous sodium acetate, melted between 205° and 206° C., and contained 24.3 percent acetic acid. Saponification of the acetate indicated a saponification equivalent of 246 and yielded the original alcohol.

A minor constituent of the ether extract was a brown tannin-lignoceric acid complex soluble in acetone or alcohol. Upon saponification this yielded lignoceric acid, neutralization equivalent 368, and a dark-colored phlobaphene.

Subsequent extraction of the ethyl ether-extracted bark with acetone in a large Pyrex-glass Soxhlet extractor gave a product that appeared to consist exclusively of a dark red tannin and phlobaphene. The tannin gave a voluminous precipitate with gelatin solution, produced a green-black color with ferric chloride solution, and was precipitated from solution with dilute sulfuric acid. Only a small part of the tannin was soluble in ethyl acetate.

The hot-water soluble extractive from bark that had been previously extracted with ether and acetone was a red-colored gum. Acid hydrolysis yielded a phlobaphene-like material and reducing sugar. Pinite, which is present in sugar pine wood, was not found in the bark.

Analysis of the bark residue after extraction with alcohol-benzene, ethanol, and hot water in accordance with conventional wood analysis procedures is contained in Table 8. The bark used for this purpose was a composite sample of the bottom, middle, and top barks.

TABLE 8.—ANALYSIS OF EXTRACTIVE-FREE SUGAR PINE BARK

Analysis	Percent of oven-dry weight of extracted bark	Percent of oven-dry weight of material
"Lignin", insoluble in 72% H_2SO_4	61.30	-----
Methoxyl in "lignin"	-----	5.37
Pentosan	7.75	-----
Methoxyl in bark	3.53	-----
Ash	0.40	-----
"Holocellulose"[1]	47.19	-----
Lignin in holocellulose	-----	23.4
Holocellulose corrected for lignin	36.15	-----
"Holocellulose"[2]	38.1	-----
Lignin in holocellulose	-----	2.8
Holocellulose corrected for lignin	37.0	-----
Cross and Bevan cellulose	41.85	-----
Lignin in C and B cellulose	-----	25.04
C and B cellulose corrected for lignin	31.37	-----
Acetyl groups	0.46	-----

[1]Holocellulose by chlorination and ethanolamine procedure
[2]Holocellulose by sodium chlorite procedure.

Discussion

The extractives from sugar pine bark, because of quantity and chemical nature, appear to have little possibility of present day utilization. Because of the low tannin content together with the dark color of the tannin itself, it appears doubtful that commercial tannin extraction for leather manufacture is feasible. Currently, there is little commercial utilization of phlobaphenes from wood or barks. These materials are rich in phenols, and it is possible that a use may be found for them in plastics, dispersants, oil-well drilling muds, and antioxidants. They are also thermoplastic and partially thermosetting. Hence, ground sugar pine

bark on heating under pressure forms a hard "plastic" board with a smooth surface. The wax content of sugar pine bark appears too low to warrant commercial extraction.

More than 61 percent of the extractive-free sugar pine bark residue consisted of a noncarbohydrate material, which was determined as lignin in the conventional lignin determination procedure. It differs from wood lignins in that it contains only one-fourth to one-third of the methoxyl groups present in wood lignins.

Roughly, 37 percent of the extractive-free bark residue was composed of a white cellulosic material, which was isolated with sodium chlorite in acetic acid solution. It was not possible to isolate this cellulose, free from lignin, by the usual chlorination procedures applicable to wood. The sum of chlorite holocellulose, "lignin", and ash residue accounted for 98.7 percent of the extractive-free bark.

Summary

The bark of ponderosa pine was found to contain 23.2 to 28.7 percent of extractives; the highest yield was obtained from the bark at the bottom of the oldest trees. Tannin content ranged between 5.6 and 11.4 percent with the highest amount found in the bark from the bottom of old trees. Sugar content of the tannin extracts was high and amounted to 30 to 50 percent of the tannin content. Other extractives were: a lignocerate wax obtained in 4.6 percent yield, a phenolic-fatty acid complex obtained in 1.7 percent yield, and a flavonol yellow coloring matter obtained in 1.4 percent yield. The latter is responsible for the characteristic yellow color of ponderosa pine bark.

The extractive-free ponderosa pine bark residue was found to consist of 51.6 percent "lignin", 46.30 percent of holocellulose, and 0.42 percent ash residue. These three components accounted for 98.3 percent of the extracted bark residue. A part of the "lignin" was tenaciously bound to the cellulose. The "lignin" was found to be a mixture of at least two substances, i.e., a low methoxyl phenolic acid and a material with 9.9 percent methoxyl groups.

Sugar pine bark was found to contain approximately 21 to 22 percent of extractives; the tannin content ranged between 4.9 and 7.1 percent, whereas the wax content ranged between 2.2 and 3.1 percent. The major extractive from this bark was a reddish-brown phlobaphene. Minor extractives were lignoceric acid and an alcohol that sublimed above 305° C.

The extractive-free sugar pine bark residue consisted of 61.3 percent "lignin", 37.0 percent holocellulose, and 0.40 percent ash residue. These three components accounted for 98.7 percent of the extracted bark residue.

Literature Cited

1. The American Leather Chemists Association. *Methods of Sampling and Analysis.* Cincinnati 21, Ohio.
2. Hubbard, J. K. and Kurth, E. F. *Douglas-fir Bark Tannin.* Presented at 114th Meeting of Amer. Chem. Soc., Sept. 14, 1948, Portland, Oreg. J.A.L.C.A. (in press).
3. Jayme, G. Cellulosechemie 20: 43–49 (March–April 1942).
4. Kurth, E. F. Tappi 32: (4) 175–176 (1949).
5. Kurth, E. F. and Kiefer, H. J. *Douglas-fir Bark Extractives.* Presented at 114th Meeting of Amer. Chem. Soc., Sept. 14, 1948, Portland, Oreg.
6. Kurth, E. F., Kiefer, H. J. and Hubbard, J. K. The Timberman. 49: 130–131 (June 1948).
7. Lewis, H. F., Brauns, F. E., Buchanan, M. A. and Kurth, E. F. Ind. Eng. Chem. 36: 759–764 (1944).
8. Ratnam, C. V. S. *Destructive Distillation Products From Douglas-fir Bark.* Master of Science Thesis, Oregon State College, 1948.
9. Wise, L. E., Murphy, M. and D'Addieco, A. A. Paper Trade Jour. 122: (2) 35–43 (Jan. 10, 1946).

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TECHNICAL SESSION IV

Tuesday, May 3, 1949, 9:00 A. M.

General Subject: Structural Uses of Wood, Adhesives and Gluing Problems

Chairman: Robert A. Cockrell, Professor of Forestry, University of California, Berkeley, California *(Southwest Regional Board Member, FPRS)*

Recorder: W. Burdette Wilkins, Consulting Engineer, Ridgewood, New Jersey *(Chairman, Northeast Section, FPRS)*

Lumber Recovery From Douglas Fir Logs in British Columbia

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The increase in quantity of lower grade Douglas fir logs on the British Columbia coast has developed interest in the most profitable use and method of manufacture. This paper shows the results of a study of three circular saw mills and three whole-log gang saw mills cutting Grade 2 and 3 Douglas fir logs. Details of overrun, lumber grade recovery, sawing time, labor costs, and lumber recovery values are submitted for logs varying in diameter from 9 to 27 inches.

Introduction

THE history of the lumber industry in the Douglas fir Region of the British Columbia coast has followed much the same pattern as that of older forest regions. In the early days, logging was carried out in the most accessible stands by selecting the best trees and taking only the choice logs. Gradually, with the introduction of power machinery, logging methods were changed; the whole stand was cut and all the logs were taken, with a resulting decrease in both log size and grade. At the present time poorer stands and more inaccessible areas are being developed. The high capital investment, high stumpage price, and the fact that the end of the mature timber is in sight have resulted in closer utilization in an effort to spread costs over a larger volume of wood and to extend the life of the operations. This has resulted in a further reduction in log size and grade. The percentage of No. 3 Douglas fir logs has increased from 13 percent in 1924 to 31 percent at the present time, with a corresponding decrease in the percentage of No. 1 and No. 2 logs.

Faced with this situation, the wood-using industry has initiated a program to integrate production by co-ordinating the activities of logging camps, sawmills, pulp mills, plywood plants, fiber-board plants, and minor wood-using industries. Some companies are now fully developed to handle the complete utilization of the tree. Plywood is made from the best logs, lumber is cut from the logs best suited to this use, and the remaining logs, together with residue from logging and sawmilling, are manufactured into pulp.

Production studies are required to determine the size and quality of log that may be used to best advantage in each process of this integration. Lumber production studies are considered to be an important factor in determining the size of log most suitable for lumber production. This paper presents a comparison of the labor costs, lumber grade production, overrun, and lumber recovery value for gang saw mills and short log circular saw mills, in order to appraise the relative value of the two methods of cutting. Grade 2 and 3 Douglas fir logs only have been considered.

Types of Mills Studied

It is recognized that no two sawmills are alike in layout, methods of cutting, or type of logs used. However, in this report an attempt is made to compare the results of a study at three circular sawmills and three whole-log gang sawmills considered fairly representative of the smaller types of sawmill. The mills studied are located on tide-water and have a daily capacity ranging from 40 to 60 M ft.b.m. per 8-hour shift. The results have been grouped in two types, namely, whole-log gang sawmills and short-log circular sawmills.

The three gang sawmills cut short logs and in addition to the whole-log gang are equipped with an edger, double-end trimmers, and green-chain. One mill also has a vertical band resaw. The kerf of the gang saws is 3/16 inch.

The three circular sawmills also cut short logs. One mill uses a double-circular head-saw, an edger, a double-end trimmer, and a vertical band resaw. The second mill is equipped with a single-circular head saw, an

edger, and a double-end trimmer. The third has a double circular head-saw, an edger, and two pony carriages which saw cants from the head-saw. Time figures for this latter mill have not been included, since the mill represents a very unusual type of layout. Grade and volume recovery, however, are considered normal and have been included in the averages with the other two mills. In all cases the kerf is 3/8 inch for the head-saw.

Manufacturing Practice

The normal length of logs arriving at the mills varies from 28 to 40 feet and it is the practice to buck these logs into two shorter logs before they enter the mill. All mills except one are "green" mills, cutting mostly for the export market, with the smaller percentage of the cut sold locally. Practically all the export lumber is sold rough and green. Common lumber for local markets is sold green S4S and the clears are usually sold rough green to a plant with dry kilns.

The lumber sizes cut run heavily to 2 inches and thicker and 4 inches and wider with a small percentage of 1-inch. Common export sizes are 2, 2½, and 3 by 5, 7, or 9 inches, with export ties being 5 by 10 in. by 8½ ft. Widths and thickness to both odd and even inches and lengths to 1-foot intervals are cut for export. Local sizes are cut to even widths and thicknesses and even lengths except in clears, which are trimmed in 1-foot intervals.

Study Procedures

Scaling

The logs were numbered in sequence, scaled, and graded on the log-deck under the British Columbia Log Rule. Average diameter, to the nearest inch, at both ends and length to the odd foot were measured. Cubic content of the logs was calculated by the Smalian formula. The log scale was computed by using average diameter at the small end and the length measured to even feet. The Douglas fir log grades used were as follows: *No. 1*—Logs suitable for flooring, reasonably straight, not less than 20 feet long, not less than 30 inches in diameter, clear, free from such defects as would impair the value for clear lumber.

No. 2—Logs not less than 14 inches in diameter, not over 24 feet long, or not less than 12 inches in diameter, and over 24 feet, sound, reasonably straight, free from rotten knots or bunch-knots, and the grain straight enough to ensure strength.

No. 3—Logs having visible defects, such as bad crooks, bad knots, or other defects that would impair the value and lower the grade of lumber below merchantable.

Culls—Logs lower in grade than No. 3.

Timing

The next step was to time the logs at the head-saw. This time is considered to be the governing factor of mill production, as the head-saw sets the pace for the rest of the mill. The rest of the mill cannot work any faster than the head-saw, and on the other hand, if the head-saw cuts too fast for the rest of the mill, the sawyer has to stop or slow down until the congestion is relieved. The time for an individual log was taken as the interval from the time the carriage was stopped in position to receive a log to the time it was stopped again to receive the next log. Delay time, such as rest periods and saw changes, which was not directly attributable to the characteristics of the log itself, was totalled and pro-rated against all logs as a percentage of the net time.

Grading and Tallying

The lumber was graded on the green chain, under British Columbia Lumber and Shingle Manufacturers' Association Standard Grading and Dressing Rules, List No. 44, by a Pacific Lumber Inspection Bureau inspector. Tallying was done so that the lumber from each log was kept separately. Nominal dimensions and length by 1-foot intervals were recorded.

Results of the Study

The Sample

Douglas fir Grade 2 and 3 logs, scaling 428,240 ft. b.m. were studied. Of this volume, 174,499 ft. b.m. was cut at the circular sawmills and 253,746 ft. b.m. was cut at the gang sawmills. At the circular sawmills the average log scaled 191 ft. b.m., with averages of 251 ft. b.m. for Grade 2 logs and 153 ft. b.m. for Grade 3 logs. At the gang sawmills the average log was 200 ft. b.m., with averages of 249 ft. b.m. for Grade 2 logs and 156 ft. b.m. for Grade 3 logs.

The logs came from various parts of the lower British Columbia coast, mostly from the east coast of Vancouver Island. The logs as sawn ranged from 12 to 26 feet in length and were placed in two length groups, 16 feet and 22 feet, for convenience in compiling. The diameters ranged from 8 inches to 28 inches and were grouped into 3-inch diameter classes for compiling. The distribution by diameter classes is shown in Table 1.

TABLE 1.—DISTRIBUTION OF LOG SIZES BY DIAMETER CLASSES USED IN GRADE RECOVERY

Diameter (Inches)	Grade 2 logs		Grade 3 logs	
	Circular mills	Gang mills	Circular mills	Gang mills
9	-------	-------	70	64
12	14	16	214	255
15	125	195	140	164
18	108	167	62	109
21	67	121	44	55
24	27	76	17	26
27	14	21	11	-------
Total	355	596	558	673
Log scale	89, 266 feet b.m.	148, 412 feet b.m.	85, 228 feet b.m.	105, 334 feet b.m.
Ave. log	251 feet b.m.	249 feet b.m.	153 feet b.m.	156 feet b.m

Sawing Time

Sawing time is considered as the basis for allocating labor costs to the various sizes of logs. The net sawing time was increased by a percentage to allocate delay time not attributable to log characteristics, but to other factors such as saw changing, mechanical breakdowns, and congestion in the mill. In the circular sawmills the delay time amounted to 5.0 percent of the net sawing time, while in gang sawmills there was a delay of 11.1 percent of the net sawing time. This delay time as distributed is shown in Table 2.

TABLE 2.—SAWMILL DELAY TIME NOT ATTRIBUTABLE TO LOG CHARACTERISTICS

Causes of delay	Circular mill	Gang mill
Allocated delay in percentage of net sawing time	5.0	11.1
Causes of delay time in percent		
Saw changes	57	50
Congestion	15	12
Mechanical breakdowns	15	20
Green-chain stoppage	9	-----
Miscellaneous	4	18
Total delay time	100	100

Lumber Recovery

Overrun. Overrun is the amount, expressed as a percentage of net scale, by which the footage of lumber produced from a log exceeds the footage predicted by the log rule used. Underrun results if the footage of lumber produced is less than that shown in the log rule.

Normally, overrun for logs scaled under the British Columbia Log Rule (which is about 3 percent lower than the Scribner Decimal C Rule) varies considerably with the diameter of the log, running as high as 40 percent for 9-inch logs and gradually decreasing to 15 or 10 percent as the diameter increases.

Overrun quoted in this paper is based on log-deck scale. As previously noted, the logs purchased by the mill are of standard lengths varying from 28 to 40 feet, with the majority being 40 feet long. In the six mills under consideration, the logs are bucked in the pond into lengths varying from 12 to 26 feet. Owing to the taper of the log and the fact that the diameter is measured at the small end this operation in itself adds considerably to the overrun. In one mill this factor was studied. First, each long log was scaled and then the scale of each of the two logs, into which it was bucked, was recorded. This overrun from bucking was found to vary from 5.7 percent for 27-inch diameter logs to 45 percent for 9-inch diameter logs, based on the water scale of the standard long logs. Details are shown in Fig. 1.

Normally, overrun from gang sawn logs is considered to be quite high and at least considerably higher than that from logs sawn in circular sawmills. However this study shows that for two of the gang sawmills cutting 2 and 3-inch material the overrun was very small. The other gang sawmill cut 2-inch lumber from the sides and 4-inch lumber out of the centre of the logs, breaking the lumber down further on the edger and the vertical band resaw. This mill showed an overrun which gradually decreased from 42 percent for 9-inch logs to 15 percent for 27-inch logs, whereas the other two gang sawmills showed in one case a practically constant overrun of 7.5 percent, and in the other case an overrun varying from 15 percent for 9-inch logs to zero percent for 27-inch logs. This lack of overrun in the two gang sawmills was due to several factors, including the following: the logs were not sorted, the gang saw crowded the edger to such an extent that the operator did not have time to get the most out of the lumber, and no attempt was made to salvage 1-inch material from the slabs.

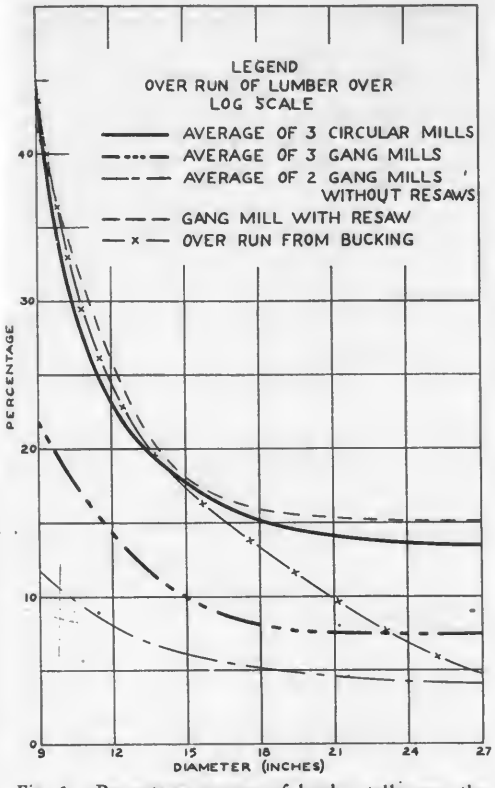
LEGEND
OVER RUN OF LUMBER OVER LOG SCALE
AVERAGE OF 3 CIRCULAR MILLS
AVERAGE OF 3 GANG MILLS
AVERAGE OF 2 GANG MILLS WITHOUT RESAWS
GANG MILL WITH RESAW
OVER RUN FROM BUCKING
PERCENTAGE
DIAMETER (INCHES)

Fig. 1.—Percentage overrun of lumber tally over the British Columbia Log Rule by diameter classes.

The overrun from the three circular sawmills was quite uniform, with the average varying from 45 percent for 9-inch logs to 13.5 percent for 27-inch logs. Fig. 1 gives curves showing the overrun obtained by bucking standard logs into shorter lengths; the average overrun for the three circular sawmills; the average overrun for the three gang sawmills; the overrun for the gang sawmill with a resaw, and the average overrun for two gang sawmills without resaws.

Relation of Cubic Scale to Log Scale and Lumber Recovery. The inadequacies of the British Columbia Log Rule are similar to those of the Scribner Decimal C Rule used in the Pacific Northwestern States. Both log rules are entirely inadequate below 12-inch diameters and the amount of lumber cut from logs of smaller diameters shows a considerable overrun, as can be readily seen by reference to Fig. 1.

The volumes of the logs studied were computed on a cubic foot basis from the Smalian formula. When the number of board feet, log scale, per cubic foot was calculated, the results showed a variation from 4.4 for logs of 9-inch diameter to 7.0 for logs of 24-inch diameter for 16-foot logs.

When the board feet, lumber tally, per cubic foot of log was calulated, the relation was found to be uniform at 7.1 for all diameters of 16-foot logs. However, length, because of the effect of taper, introduces a variable, and as the length of the log increases the board-foot cubic-foot relation decreases on both the log scale and lumber tally basis. This trend has

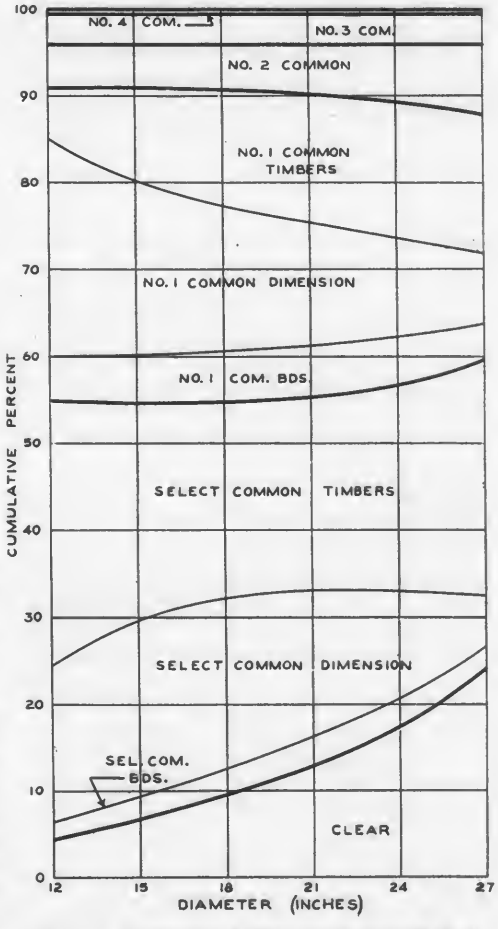

Fig. 2.—Cumulative lumber grade percentages by diameter classes for grade 2 Douglas fir logs cut at circular mills.

been observed for 16- and 22-foot Douglas fir logs and for 16-foot Engelmann spruce logs.

Grade Recovery. Lumber grade recovery for each grade of logs was similar for both circular and gang sawmills. The grade recovery followed the normal trend of an increase in the clear grades with increase in log diameter and log grade, whereas the common grades tended to decrease with increase in log diameter. The figures show the percentage of boards, dimension, and timbers in the Select Common and No. 1 Common grades, and it is in these divisions that the major differences occur. The cut of the gang mills was practically all dimension stock, whereas the cut of the

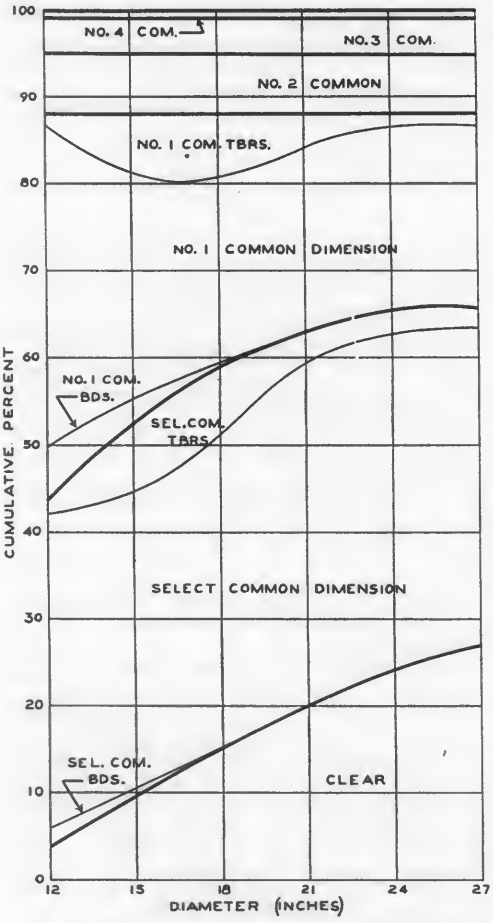

Fig. 3.—Cumulative lumber grade percentages by diameter classes for grade 2 Douglas fir logs cut at gang mills.

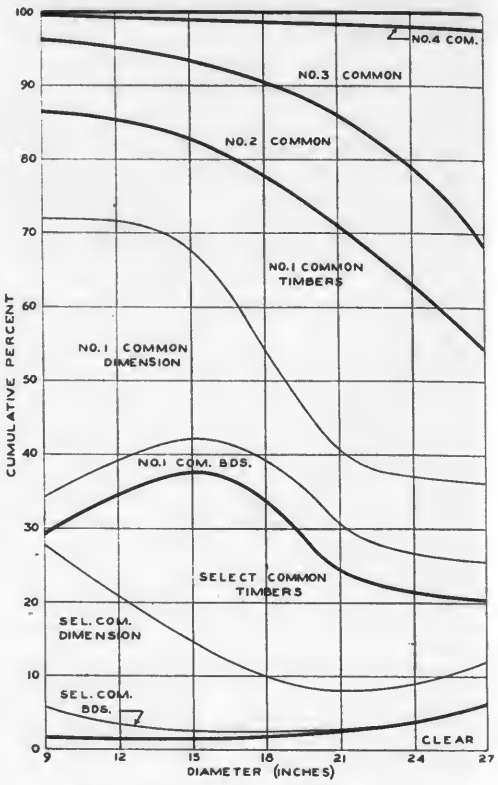

Fig. 4.—Cumulative lumber grade percentages by diameter classes for grade 3 Douglas fir logs cut at circular mills.

circular mills ran to a high percentage of timbers.

Figs. 2 to 5 show the average percentage in lumber grade recoveries by log diameter for Grade 2 and 3 logs cut by the circular and the gang sawmills.

Labor Costs

As stated previously, sawing time is considered to be the governing factor in sawmill production. The sawing time per M ft. b.m., lumber tally, is used as a basis for allocating labor costs for the mill from pond to greenchain. The labor costs include wages for all employees actually engaged in the manufacturing processes of the mill, including carrier drivers, but not power-house employees. The hourly wages for the key men are as follows.

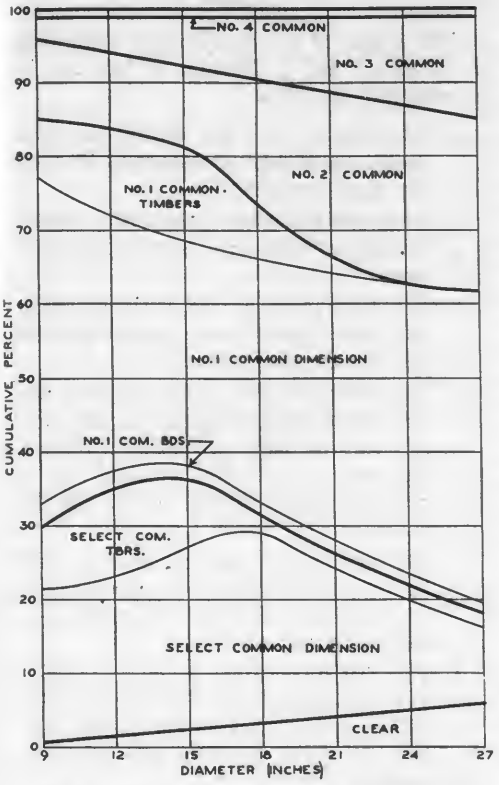

Fig. 5.—Cumulative lumber grade percentages by diameter classes for grade 3 Douglas fir logs cut at gang mills.

Other rates may be taken as in normal relation to these.

Circular sawyer	$2.16	per hour
Gang sawyer	1.45	per hour
Edger man	1.47	per hour
Trimmerman	1.17½	per hour
Green-chain puller	1.12½	per hour
Boomman	1.17½	per hour
Laborer	1.08	per hour

The labor costs of operating the circular sawmills averaged 49 cents per minute, or $29.52 per hour, while for the gang sawmills the labor costs averaged 59 cents per minute, or $35.28 per hour.

When these figures are applied to the sawing time, the labor costs of sawing logs of various diameters are obtained as shown in Table 3. These necessarily show the same trend as the sawing time per M ft. b.m. and indicate that for 16-foot logs gang sawmills have a higher labor cost by $0.85 for 9-inch diameter logs, but that for 12-inch diameter logs the gang sawmill costs and circular sawmill costs are practically identical at $6.99 and $6.96 respectively. For 27-inch logs the gang sawmill labor cost is $1.24 less than the circular sawmill labor cost. From these figures it is apparent that gang sawing is a cheaper method than circular sawing, except when logs below 10 inches in diameter are used.

Determination of Log Values

Prices

The following prices per M ft. b.m. were used to calculate lumber recovery values for the various sizes of logs. These values are taken as being close to the market price, f.o.b. the mill, for the Canadian rail market as of March 1, 1949, and are based on the same price spreads as appear in the Market Survey, No. 49–1, published by the British Columbia Lumber Manufacturers' Association. In the clear grades the price was adjusted on the basis of 50 percent B and Better and 50 percent C Clear for No. 2 logs, and on the basis of 33⅓ percent B and Better and 66⅔ percent C Clear for No. 3 logs. In the Select Common and No. 1 Common the timber prices have been adjusted to allow for the higher price of ties for the circular sawmills.

TABLE 3.—LABOR COSTS (DOLLARS PER M b.m.) AND SAWING TIME PER M b.m.

Diameter (Inches)	16-foot logs				22-foot logs			
	Circular		Gang		Circular		Gang	
	Sawing time per M b.m. (min.)	Cost ($)	Sawing time per M b.m. (min.)	Cost ($)	Sawing time per M b.m. (min.)	Cost ($)	Sawing time per M b.m. (min.)	Cost ($)
9	22.3	10.98	20.1	11.83	17.5	8.61	16.9	9.95
12	14.2	6.96	11.9	6.99	11.6	5.72	10.9	6.40
15	11.5	5.64	8.8	5.18	9.5	4.70	8.0	4.71
18	10.2	5.00	7.3	4.29	8.7	4.28	6.7	3.93
21	9.6	4.73	6.5	3.80	8.4	4.12	5.9	3.49
24	9.5	4.65	6.0	3.53	8.3	4.09	5.5	3.22
27	9.5	4.67	5.8	3.43	8.3	4.10	5.2	3.06

Lumber Recovery Value

The values of lumber recovery per M ft. b.m. from logs in the different diameter classes have been calculated from the above lumber prices and are shown in Table 4.

TABLE 4.—PRICES USED (PER M b.m.)

	Clears Gang and Circular Mills No. 2 Logs—$92.50	No. 3 Logs—$91.70
	Commons	
	Circular Mill	Gang Mill
Select Common 1"	$49.00	$49.00
Select Common 2"	51.00	51.00
Select Common Timbers	67.50	64.00
No. 1 Common 1"	46.00	46.00
No. 1 Common 2"	48.00	48.00
No. 1 Common Timbers	62.50	60.00
No. 2 Common	43.00	43.00
No. 3 Common	32.50	32.50
No. 4 Common	22.50	22.50

The lumber recovery values for Grade 2 logs show a value of $2.80 more for circular sawmills than for gang sawmills in logs of 12-inch diameter and $4.70 higher for 27-inch logs. In both cases the lumber recovery value shows a straight line increase. Grade 3 logs cut by circular sawmills show a value higher than those cut by gang sawmills with the difference increasing from $1.40 for 9-inch logs to $4.90 for 21-inch logs, and decreasing to $3.60 for 27-inch logs. It is interesting to note that the value of Grade 3 logs increases up to 15 inches and thereafter drops. This rise is due in part to the fact that logs smaller than 14 inches and less than 24 feet long are not allowed in Grade 2. Lumber recovery values are shown in Table 5.

TABLE 5.—LUMBER RECOVERY VALUES PER M b.m.

Diameter	No. 2 logs		No. 3 logs	
	Circular mills	Gang mills	Circular mills	Gang mills
Inches	Dollars per M b.m.	Dollars per M b.m.	Dollars per M b.m.	Dollars per M b.m.
9	-----	-----	51.20	49.80
12	55.50	52.70	52.50	51.80
15	57.40	54.30	53.60	51.40
18	59.40	55.90	53.40	49.50
21	61.40	57.40	53.00	48.10
24	63.30	59.00	52.20	47.70
27	65.30	60.60	51.20	47.60

The great difference between prices of dimension and timbers accounts for the difference in lumber recovery values between the gang and the circular sawmills.

Summary

The results of this study of the sawmilling of Grades 2 and 3 Douglas fir logs can be summarized as follows:

1. The sawing time per M ft. b.m. was higher for the circular sawmills than for the gang sawmills.
2. Labor costs per hour were lower for the circular sawmills than for the gang sawmills.
3. The labor costs per M ft. b.m. lumber tally were higher for the circular sawmills than for the gang sawmills.
4. The overrun of the circular sawmills was fairly uniform and higher than the average for the gang sawmills. However, one gang sawmill with a resaw had an overrun similar to that of the circular sawmills.
5. The lumber grade recovery was very similar for both circular and gang sawmills but the circular sawmills cut a higher percentage of timbers.
6. This difference in the volume of timbers was responsible for the fact that the value of lumber produced by the circular sawmills was higher than that from the gang sawmills.
7. The lower cost per M ft. b.m. of operating the gang sawmills was more than offset by the higher value of the products produced by the circular sawmills.

Conclusions

The results of this study indicate that for lumber prices used and present day wage rates circular sawmills will produce a higher profit than gang sawmills. Taking labor costs two years ago and Canadian controlled prices, however, there is very little difference between the two types of mill.

The fact that one gang sawmill, by using a resaw and by sorting logs, was able to increase its overrun above that of the other two gang sawmills appears to indicate that gang sawmill operations must be carefully planned to get the most out of a log. Careful sorting of logs, changing saw patterns to suit each sort of log, cutting the size of logs best suited to produce a given order, and cutting 1-inch material from

the sides of the log are necessary for an efficient gang sawmill operation.

The method of using two gang saws in tandem, as practised in Sweden, may be the most successful application. In this system a slab and possibly an inch board are taken off each side of the log in the first gang, leaving a cant in the center, which is then turned down and cut by the second gang. This method fully utilizes the log and takes full advantage of the cutting accuracy of gang saws by producing a high percentage of boards gang-sawn on four sides.

Live-sawing a log into 2-inch lumber as practised in two of the gang sawmills studied produces heavy edgings and fails to utilize 1-inch boards from the slabs.

Further study of the various methods of gangsawing lumber are necessary before a complete picture can be obtained.

Discussion

A. C. Knauss (U. S. Forest Service): It is interesting to compare with the results presented by Mr. McBride similar data obtained in three studies on lumber grade recovery from Douglas fir in the United States. Elmer E. Matson, Pacific Northwest Forest and Range Experiment Station at Portland, Oregon reports the following results on a study made in a southern Oregon sawmill, cutting logs from a 200- to 300-year age class Douglas fir stand. The mill is equipped with a band headrig and a resaw. Logs 22 inches and over produced an overrun of 10 percent. Smaller logs yielded higher overrun values, the 10-inch diameter class showing a value of 50 percent.

In another study at a circular mill (not equipped with a resaw) logs from a forest stand with 85- to 135-year age class were cut into dimension and timbers. Twenty-four inch and larger diameter logs showed an overrun of 12 percent. The 10-inch diameter class produced an overrun of 27 percent.

In a third study small logs were put through a Swedish gang and edger-equipped sawmill producing boards and dimension. The 10-inch diameter class of logs here yielded an overrun of 46 percent.

Mr. McBride: It is interesting to note how closely the figures on overrun for band and circular mills quoted by Mr. Knauss agree with the figures found in British Columbia for the larger logs. The small difference can be accounted for by the spread between the B. C. Log Rule and the Scribner Log Rule.

The figure of 46 percent overrun obtained at a Swedish gang mill is in line with that normally expected from mills of this type when logs are sorted and the saw pattern is set up to suit each log sort. This figure is comparable to that obtained in our study at the Swedish gang mill which sorted logs for size and was equipped with a re-saw.

Robert A. Cockrell (University of California): In spite of comparable values of output, isn't there a greater loss of wood through sawdust because of wider kerf of circular saws over gangsaws? Most circular saws that I am familiar with have 3/8-inch teeth and if there are any irregularities in alignment, there is an additional loss. Blades highly tensioned in a gangsaw frame surely can be kept in true alignment and usually have a 3/16-inch kerf. Possibly this could be reduced to 1/8-inch.

Mr. McBride: There is no question that the circular saws cut more wood into sawdust than gang saws. However, our studies show that this is offset at the edger where the quantities of solid waste and sawdust are both heavier than for the circular mills. This is caused by at least three factors: (1) every board from the gang mill has to be edged on both edges; (2) in the mills studied the edgerman was crowded so that he had insufficient time to set the saws for each board; and (3) the edger cuts the taper out of two sides of the log.

FOREST PRODUCTS RESEARCH SOCIETY

Evaluation of Resin Adhesives

Robert P. Hopkins

Plywood Group Leader, Rohm and Haas Co., Resinous Products Division, Philadelphia, Pa.

Test methods available for the evaluation of resin adhesives for wood have been the subject of considerable discussion because of the difficulty encountered in correlating these tests with service conditions. This paper contains a detailed study of the influence of constructional variations of the test specimen on the performance of resin adhesives in laboratory cycle- and outdoor-exposure tests. The data points up the importance of a better recognition of the physical stresses in a glue line if more indicative evaluation tests are to be realized. The test procedures have been based on commercially available resin adhesives.

Introduction

THE 14-year commercial development of synthetic resin adhesives for the wood industry in this country resulted in a national consumption of some seventy-five million pounds of these materials during 1948 *(2)*. Among the primary reasons for such wide acceptance has been the quality imparted to the bonded wood by these resins. The order of glue joint quality may vary from the water resistant property of flour-extended urea formaldehyde resins on up to the weather resistant character of melamine and the phenolics.

The test methods employed by resin producers, consumers and interested government agencies to estimate the general limits of use for the various adhesives, are of a limited variety. Outdoor exposure tests, tensile shear on plywood specimens before and after immersion in boiling water or water at room temperature, and compression shear on laminated wood comprise the commonly used tests for evaluating the resin glues. These tests have generally prevented the selection of a resin, or bonding conditions for that resin, which would not do the job for which it was intended. Nevertheless few persons familiar with adhesives fail to recognize the negative nature of these tests as indicated by their inadequacy to estimate performance of the resins under a wide variety of service conditions. (This problem of course is by no means peculiar to the field of adhesives.)

The famous British Mosquito plywood bomber used in the past war contained cold setting urea formaldehyde assembly glues *(7)*. Tests conducted by the British provided data which resulted in government approval of urea formaldehyde adhesives in this application. Yet there is little test data in this country to recommend U/F resins for such use. There is a divergence of opinion on the performance of the ureas in the Mosquito but the important point to realize is that discrepant opinions of the U/F resins resulted from tests by different agencies.

I am familiar with satisfactory results obtained on unprotected laminated one-inch and two-inch Douglas fir lumber, cold bonded with a urea formaldehyde resin and exposed outdoors for four years. The condition of the glue lines at the end of that period was very satisfactory—but outdoor exposure studies on birch plywood showed the same resin to be unsatisfactory in far less time.

Undoubtedly many of you could provide a list of similar examples of the above variations or discrepancies. At any rate, the desirability of obtaining better concrete information on factors governing resin performance should be apparent to us all. For example, an adhesive may be known to suffer chemical degradation through embrittlement, prolonged exposure to water, or certain temperatures and humidities, etc. Such degradation can be readily detected by exposure of simple plywood specimens to these various conditions. But these chemical degradation tests lose much of their significance when they either do not obtain in actual service or when other causes of deterioration, primarily physical stressing of the glue line are of as much concern as the degree of chemical durability of the glue. It is the latter influence which needs better study to aid in obtaining more realistic evaluation procedures.

Published information on the subject of evaluating adhesives for the wood industry in-

cludes extensive work done at the Forest Products Laboratory at Madison, Wisconsin *(11, 5, 1)*. Dietz and Grinsfelder have discussed the effect of mechanical stresses on phenolic bonded plywood *(4)*. Truax and Selbo reported on a rapid method for determining the durability of glue joints in laminated beams *(10)*. Perry cautions against generalizations on the permanence of boil-resistant glues *(9)*. Marra has called attention to the relationship of stress factors set up by moisture gradients in different wood constructions *(8)* while Delmonte reviews the generally used tests for wood adhesives quite thoroughly *(3)*.

In the hope that the aims of the Society might be served, particularly insofar as they relate to providing data on test methods and procedures, we offer the following information on the testing of resin glues.

A recent investigation at our laboratory was undertaken to provide us with a better understanding of some of the factors affecting the performance of resin adhesives on wood. General relationships of construction, wood species, etc. to glue performance were of course common knowledge but curiosity as to the extent of these relationships was the motivating force for our work. In such a study the vagaries of laboratory cycling test procedures also were of interest. We believed the knowledge to be gained was fundamental to further efforts to approach the goal of indicative performance tests. Therefore both outdoor exposure and laboratory soak-dry tests were conducted on representative types of resin adhesives. (In view of the seasonal variations in atmospheric conditions the entire exposure studies on the various panels were made in the same period.) The study was concerned essentially then with the resistance of the resins to physical stresses applied to the glue lines by the bonded wood itself.

Comparison of the Effect of Veneer Thickness on the Strength of Resin Glues

Our first efforts to study the behavior of resin adhesives in different constructions were concerned with the three-ply $\frac{1}{16}$ in. yellow birch veneer panels familiar to you who have tested resin glues. This construction was compared to a three-ply $\frac{1}{8}$ in. birch veneer panel using various types of resins. The comparison was based on tensile shear testing of the conventional $3\frac{1}{4}$ by 1-inch specimen and on observation of the amount of edge delamination of the panels exposed outdoors.

The behavior of the glues in various modifications of conventional soak cycle tests was observed to determine whether by chance we might be able to approximate some relationship with the exposure tests. Moreover we were not so much interested in comparing the water resistance or exposure resistance of the various adhesives as we were in noting the extent of the stress variations regardless of the glues.

Table 1 contains tensile shear strength data obtained with the two panel constructions after completion of various tests. Data are listed for the edge delamination observations made half way through the exposure period and immediately prior to cutting the panels for final shear strength determinations. An effort was also made to determine the percent of shear strength retained by the three-ply $\frac{1}{16}$ in. and three-ply $\frac{1}{8}$ in. veneer panels. Test procedures are described in the appendix.

Reviewing the information contained in Table 1 in the order of its significance, it will be noted that there is strong evidence that three-ply $\frac{1}{16}$ in. panels provide a somewhat more severe test of the glue than three-ply $\frac{1}{8}$ in. panels under conditions of outdoor exposure. An average shear strength retention of 32.8 percent resulted with the three-ply $\frac{1}{16}$ in. construction bonded with the five various resin adhesives tested. This value is to be contrasted to an average shear strength retention of 51.4 percent for the three-ply $\frac{1}{8}$ in. panels. Moreover in support of the consistently lower shear strength retention observed with the $\frac{1}{16}$ in. veneer plywood was the edge delamination noted with the panels made with veneers of this thickness and cold bonded with urea formaldehyde resin.

The above differences are chiefly attributable to the greater amplitude of stresses set up on the glue lines of the $\frac{1}{16}$ in. veneer panels. These stresses result from the wetting and drying of the wood. Under similar conditions $\frac{1}{16}$ in. veneer reaches a higher moisture content or a given moisture content faster than is the case

TABLE 1.—COMPARISON OF VENEER THICKNESS IN BIRCH PLYWOOD CONSTRUCTION

Panel construction	Resin type	Bonding temp.	Initial Tests				Tests after Outdoor Exposure			
			Dry shear	Soak dry cycle	Soak dry boil dry	Soak dry 2 boil cycles	Edge delam. after 9 months	Edge delam. after 18 months	Dry shear after 18 months	Shear strength retained
		°F.					Percent	Percent		Percent
Three ply ⅛ in.	urea formaldehyde	80	402–13	318–00	delam.	------	100	---	none	0
" " ⅛ in.			457–19	336–00	delam.	------	36	100	148– 0	32
" " ⅛ in.	fortified urea formaldehyde	240	532–64	460–16	336–05	213–00	3	32	178–17	33
" " ⅛ in.			605–71	528–56	350–00	175–00	0	3	299–30	49
" " ⅛ in.	urea formaldehyde	240	497–68	419–06	139–00	delam.	---	100	none	0
" " ⅛ in.			596–21	473–00	delam.	------	37	100	146– 3	26
" " ⅛ in.	phenol formaldehyde	300	534–50	562–47	542–64	527–51	0	0	370–55	69
" " ⅛ in.			589–48	546–61	586–69	528–58	0	0	442–53	75
" " ⅛ in.	resorcinol formaldehyde	140	444–74	363–75	344–71	331–74	1	2	278–45	62
" " ⅛ in.			519–58	497–40	493–53	466–47	0	0	392–51	75

with 1/8 in. veneer. Likewise the 1/16 in. veneer of a given wood species loses its moisture faster than the 1/8 in. veneer.

The laboratory cycle tests on plywood, despite being composed of a combination of the soak cycle and boiling water cycle used in many specifications, obviously tend to overestimate the outdoor durability of phenolics on *plywood* constructions. (It should be noted here that we are speaking in relative terms and that the comments are being made on the behavior of a resin in constructional variations. The actual bond strength of the phenolics after outdoor exposure is satisfactory.)

This relative "overestimation" of phenolic resin durability in plywood tests will be contrasted later to the performance of phenolics and other types of resins in similar tests but on different constructions.

Comparison of Cross Ply Versus Laminated Construction

In developing our study of the inherent stress relationships of construction to glue line strength, a brief comparison was made of three-ply 1/8 in. veneer plywood (cross ply) and three-ply 1/8 in. laminates (parallel grain). The comparison was restricted to edge delamination readings after outdoor exposure since the badly cupped condition of the laminates prevented any shear tests.

The data illustrate the increased severity of the stresses developed on the glue by using the cross ply construction characteristic of plywood.

Comparison of Total Thickness of Laminates in Parallel Grain Construction

Tests were next made on laminated specimens glued up from members of different thicknesses. White oak sections 2 1/2 by 12 by 3/4 in. were bonded with the four resin formulations listed in Table 3. For this study of the effect of wood thickness on glue line performance, two-ply and four-ply laminates were tested. The laboratory cycling procedure was identical with that described in the appendix. In some cases the shear values reported for the outdoor exposure samples are higher than those listed for the initial dry strength of the glue. This may be attributable to the fact that stronger wood may have been used in the outdoor specimens, although the wood used for a given glue was generally quite uniform.

It is particularly noteworthy that the 1 1/2 year exposure showed no perceptible degradation of the glues while a definitely deteriorating effect was observed in the laboratory cycling tests. Little difference exists between the effect of the two- and four-ply laminated lumber on the glues, probably because of little variation in the density of the laminae.

The excellent shear strength recorded for the exposed oak laminate bonded with the fortified urea is certainly in contrast to the marked degradation observed in the plywood tests. Since the laboratory cycle tests in both types of specimens showed similar deterioration of the glue, the laminated oak apparently fails to develop the stresses of three-ply 1/16 in. birch plywood.

The data on the water resistant phenolic resins also makes it quite clear that inherent in the degrading influences of cycle tests on the glues are the equally destructive influences on the wood. The persistent falling off of shear strength with slight changes in wood failure points up an example of the objectionable character of laboratory cycling tests. The oak is stronger after being exposed to the elements for 18 months than after being soak cycled and given one four hour boiling water immersion.

Effect of Use of Thin Veneer Core in Maple Laminates

Continuing the study of the effect of constructional variations on the strength of resin

TABLE 2.—EFFECT OF GRAIN DIRECTION OF WOOD ON GLUE LINE OF ONE FOOT SQUARE PANELS

Resin	Bonding Temp.	Construction	Edge delamination	
			After 9 months	After 18 months
	°F.		Percent	Percent
Urea formaldehyde	80	cross ply	36	100
		parallel ply	19	62
Urea formaldehyde A	260	cross ply	100	---
		parallel ply	20	60
Urea formaldehyde B	260	cross ply	47	100
		parallel ply	11	37

TABLE 3.—COMPARISON OF TOTAL THICKNESS OF LAMINATES IN PARALLEL GRAIN CONSTRUCTION

Resin	Bond. temp.	2 by ¼-in. Oak Laminates					4 by ¼-in. Oak Laminates				
		Compression Shear Test[1]									
		Initial					Initial				
		Dry shear	Soak dry	Soak dry boil	Soak dry boil	18 months dry shear	Dry shear	Soak dry cycle	Soak dry boil	Soak dry boil	18 months dry shear
	°F.										
Phenolic	190	2217–82	2012–76	2014–82	2096–95	2200–61	2385–79	2164–90	1632–65	1293–73	2175–74
Resorcinol–paraformaldehyde	140	2413–75	2153–87	1975–69	1990–62	2503–77	2165–92	1917–73	1725–81	1659–80	2565–80
Resorcinol–aqueous formaldehyde	77	1997–98	2121–84	1993–91	1874–97	2173–60	2064–98	1805–93	1829–90	1395–78	2257–78
Fortified urea	140	1682–93	1502–65	658–10	Delam.	1982–88	1705–98	1398–75	330– 6	274–10	1764–91

[1] Regular Spec. ANG-8 test.

adhesives, attention was given to the construction commonly used for obtaining compression shear test specimens. Laminated two-ply ¾ in. maple blocks, 2½ by 12 in., whose specific gravity was above 0.65, were bonded with a resorcinol resin at room temperature. This construction was compared to another laminated maple block having a $\frac{1}{16}$ in. veneer core. The following comparison demonstrates variable deterioration on a given glue produced in similar tests by varying the construction of the specimen.

TABLE 4.—EFFECT OF USE OF THIN VENEER CORE IN MAPLE LAMINATES

Type Resin	Bonding Temp. °F.	Construction	Initial dry shear	Soak dry cycle	Soak dry boil dry	Soak dry 2 boil dry	Dry shear after 18 months outdoor exposure
resorcinol	80	two-ply ¾ in. laminate	3151–71	1853–42	1969–64	852–23	3067–76
formaldehyde	80	core-modified laminate	2738–95	2781–100	1837–90	1667–40	2188–70

The simple maple laminate maintained excellent strength outdoors with the resorcinol resin but showed pronounced deterioration in the cycles of room temperature water immersion and drying at 140° F. By contrast the $\frac{1}{16}$ in. core-modified laminate showed a more noticeable loss in strength outdoors than on the room temperature water immersion—140° F. dry cycle tests.

The regular maple laminate is capable of ultimately greater stress on the glue than the veneer modified laminate if conditions are severe enough as indicated by the comparison of the cycle test data. The latter specimen however is more prone to develop stress as a result of moisture content gradients because of the presence of the thin veneer. (Note outdoor exposure shear strength.)

Effect of Size of Test Specimen

The outdoor exposure work described thus far was done on 10½- by 10½-inch plywood panels or 2½- by 12-inch laminated blocks. We were naturally interested in the effect of a given test condition on different size specimens, particularly on the conventional 3¼- by 1-in. plywood tensile shear specimen and the 2- by 1½-in. maple block compression shear specimen.

Three test sample sizes were observed on three-ply $\frac{1}{16}$ in. yellow birch plywood: (1) 12 by 12 in.; (2) 6 by 12 in.; (3) 3¼ by 1 in. The maple block exposure comparison was restricted to a comparison of the compression shear specimen to the regular 2½ by 12 in. blocks from which the shear specimens are cut. A phenolic resin film glue was used in the preparation of the plywood while a now obsolete resorcinol type was employed for the maple blocks.

The dry shear exposure data reported in Tables 5A and 5B were obtained after an outdoor exposure period of 18 months in Philadelphia. All shear specimens of course were of standard size when tested.

TABLE 5A.—PLYWOOD TENSILE TEST DATA ON SPECIMENS OF DIFFERENT SIZE

Original construction	12 by 12 in.	6 by 12 in.	3¼ by 1 in.
Final Dry Shear	355–68	341–44	297–30
Initial Dry Shear	------	------	514–07

TABLE 5B.—MAPLE BLOCK SHEAR DATA ON SPECIMENS OF DIFFERENT SIZE

Original construction	2½ by 12 in.	1½ by 2 in.
Final Dry Shear	1340–00	specimens delaminated
Initial Dry Shear	-------	2912–11

With either specimen or wood species an inverse relationship of size of specimen to severity of test is indicated. It is believed that a greater latitude of moisture content gradients occurs with the smaller specimen thus creating more pronounced stressing of the glue line.

Influence of Wood Species on Glueline Strength

Any attempt at demonstrating the common causes of glue line stress which did not consider the effect of the wood species would be incomplete. Laminated two-ply ¾ in. sugar maple blocks, similar to the type referred to previously, were compared to white oak in a similar construction. The tests employed are also similar to those described in the appendix. A resorcinol formaldehyde resin of lower reactivity than those now commercially available was used with paraformaldehyde and 37 per-

cent aqueous formaldehyde "catalyst" (actually resin formers). Elevated temperatures were used in bonding the resorcinol resin-paraformaldehyde system while only room temperature was used in preparing the laminates with the resorcinol resin-aqueous formaldehyde glue. The following data on the two wood species simultaneously demonstrate the effect of state of cure of the resin.

TABLE 6.—EFFECT OF WOOD SPECIES ON BOND STRENGTH

"Catalyst"	Bonding temp.	Specimen construction	Initial dry compression shear	Soak dry cycle	Soak dry 1 Boil	Soak dry 2 Boil	18-month outdoor exposure dry shear
	°F.						
Paraformaldehyde	140	maple laminate	2912–11	547–02	delam.	-------	870–00
Paraformaldehyde	140	oak laminate	2143–75	2153–87	1975–69	1990–62	2503–77
37 percent aqueous formaldehyde	77	maple laminate	3152–71	1853–42	1964–64	852–23	3067–76
87 percent aqueous formaldehyde	77	oak laminate	1997–98	2121–84	1993–91	1874–97	2176–60

Greater stresses are set up by the maple and the only reliable way of compensating for the increased stresses is by improving the degree of cure of the resin. In the above example this was accomplished by using aqueous formaldehyde which is a more reactive source of formaldehyde than paraformaldehyde. Generally however attention to bonding conditions accomplishes the same purpose.

Significance of the Information Obtained

This phase of our investigation of factors governing the behavior of resin adhesives has provided us with something other than broad generalizations. As stated in the fore part of this paper, it had been known that wood species, and particularly the construction of glued wood, had a bearing on the performance of a resin. We did not realize the reversal of deterioration trends in laboratory versus outdoor exposure tests dependent upon differences in construction and species of the glued wood. The importance of the size and construction of a specimen on the performance of a resin glue in a test is apparent.

No one questions the fact that ultimate stresses produced by a given moisture gradient are greater in lumber than in veneer, or in cross ply constructions as opposed to laminated constructions. What must be questioned is how closely the conditions of use come to approaching the development of the ultimate stresses of various assemblies regardless of construction. Equally questionable is how closely the conditions of use come to the conditions (temperature, humidity, etc.) at which a given resin might be known to suffer chemical degradation. The absence of better information on these two important considerations constitutes a primary failing in the conclusions derived from commonly used evaluation procedures.

A phenolic glue film which opened the door to the development of resin adhesives for wood in this country was found to suffer significant strength loss when exposed outdoors in the standard three-ply $\frac{1}{10}$ in. birch tensile shear specimen. Yet larger exposure specimens (12 by 12 in. and 6 by 12 in.—Table 5A) show little strength loss and in the fourteen years of the resin's commercial use in aircraft, furniture, etc. not a single failure has been reported. Accelerated temperature and humidity test data on urea resins published by a government agency *(6)* also showed degradation when the same type specimen was used. Yet the urea formaldehyde resin adhesive is also a proven product.

We believe this work lends further weight to the argument for designing tests which include more realistic information on the amount of physical stresses set up by various wood constructions. The present character of evaluation procedures for wood adhesives overemphasizes possible chemical degradation of the resin after exposure to water, humidity, temperature, etc. Such information is obviously essential but a better balance is needed with information to be gained from the amount of inherent stresses which actually occur in the glued wood in the type of service for which it is intended. At least that is the conclusion we have arrived at in the face of the reported information showing e.g., greater deterioration of resin bonded plywood panels on outdoor exposure than in laboratory cycle tests as contrasted to the opposite effect on laminated blocks.

Resin adhesives have gone far in broadening the utilization of wood. They can go farther still if an effort is made to better understand the general conditions, particularly the extent of stresses, existent in a resin bonded joint in actual service. This is a combined task for the chemist and engineer. We know of no better place to look for such coordination of effort to improve the utilization of glued wood than in this Society.

Acknowledgment

The writer wishes to acknowledge the contributions of H. Grinsfelder and R. F. Hill to the work described herein.

APPENDIX

TEST PROCEDURES USED FOR EVALUATION OF THE RESINS

Laboratory Testing

Standard tensile shear tests were made on 3¼ by 1 inch specimens while standard compression shear tests were conducted on laminates.

"Dry strength" was determined after conditioning specimens to an equilibrium moisture content of eight to ten percent.

"Soak-dry cycles" referred to in the tables consisted of a 16 hour immersion in water at room temperature followed by an eight hour drying period at 140° F. Five cycles were employed.

"Soak-dry-boil-dry" cycles consisted of a 4 hour boil and a 20-hour dry at 140° F. following the above described five soak-dry cycles.

"Soak dry 2 boil cycles" consisted of the previous tests followed by a second 4-hour boil—20-hour dry at 140° F.

All testing on the cycle specimens was done after conditioning to equilibrium moisture content at 75° F. and 55 percent relative humidity (about 10 percent moisture content).

Outdoor Exposure Testing

"Dry shear" was done on standard 3¼ by 1 in. specimens taken from 10½ by 10½ in. exposed plywood panels or on 2 by 1½ in. specimens taken from 12 in. long laminates.

"Edge delamination" is expressed in percent and is based on readings (up to) one inch from the edge of the panel along the entire edges. The percent delamination is based on the average area delaminated in the one-inch depth divided by the total area along the edges.

References

(1) Blomquist, R. F. Summary of available data on the stability of glue joints in laminated oak keels in fresh and sea water. Forest Products Laboratory Report No. 1383. January 1943.

(2) Bureau of Census. Modern Plastics 26, No. 5.

(3) Delmonte, J. Technology of Adhesives, pp. 488–496. New York. 1947.

(4) Dietz, A. G. H. and Grinsfelder, H. Paper presented at Woodworking Industries meeting of Am. Soc. Mech. Eng. December 3, 1943.

(5) Eickner, H. W. Durability of glue joints between blocks of compreg and wood. Forest Products Laboratory Report No. 1536.

(6) Gabriel, E. A. Experiments to develop a rapid durability test for urea resin glues. Forest Products Laboratory Report No. 1533.

(7) Knight, R. A. G. Communication. Forest Products Research Laboratory of England.

(8) Marra, A. A. Technology of the glue line in electronic edge-gluing of lumber. F. P. R. S. Proc. Vol. 2. p. 253. 1948.

(9) Perry, T. D. Modern Wood Adhesives. 189 pp. illus. New York.

(10) Truax, T. R. and Selbo, M. L. Accelerated durability tests on resin bonded oak keels. Trans. A. S. M. E. pp. 393–400. May 1948.

(11) Wangaard, F. F. Summary of information on the durability of aircraft glues. Forest Products Laboratory Report No. 1530. Rev. 1946.

Discussion

James F. Hamilton (Perkins Glue Company): The thorough understanding and experience obtained through many years of use with one type of adhesive, let us say casein or vegetable glue, results in long established techniques and procedures. Such techniques and procedures do not necessarily apply to the resin type adhesives. It is very important,

therefore, that the resin glue user review carefully the data prepared by the adhesive supplier.

If there are points that need clarifying, they should be discussed so that the glue user has a clear concept of the conditions of use as they apply to the veneer, lumber, moisture content, curing conditions, and other significant factors as well as the glue formula itself. After gaining this clear concept of use, the gluing departments should be instructed not to deviate from the procedure or proper use of the glue as obtained.

Mr. Hopkins: Mr. Hamilton raises a very important point in calling attention to the fact that old test procedures for nonresinous glues are not suitable for pointing up the merits of resin glues. However, the point to be made is that even conventional test procedures for resin adhesives are inadequate in estimating performance limitations and are therefore in need of revision. The important relationship of the test specimen to apparent behavior of the adhesive, illustrated in this paper, is a factor which has received little consideration in devising tests for resin glues.

Glen P. Harris (Monsanto Chemical Company): I agree with Mr. Hopkins' comments on the need for methods of testing wood adhesives which will supplement those we now have. There has been confliction of test data obtained by industrial and independent laboratories in the field performance of resin adhesives.

Mr. Hopkins: Mr. Harris' practical experience in the field of resin adhesives and his acquaintanceship with the inadequacy of available test methods in tying in actual performance typifies a situation which makes it questionable whether even the less durable types are being fully developed.

FOREST PRODUCTS RESEARCH SOCIETY

Development of Working Stresses for Stress-Grade Lumber

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American Lumber Standards provide three principal use classifications for grading lumber. They are: (1) Shop and Factory Grades, (2) Yard Grades, and (3) Stress or Structural Grades. Shop and factory grades are based on the number and size of clear cuttings; yard grades, on appearance and general utility; and stress or structural grades, on strength. This paper deals only with the stress grades, because working stresses can be assigned only to grades in which defects are limited in accordance with their effect on the strength.

Background

FORTY years ago engineers, architects, and users were demanding safe and economical working stresses for timbers. To meet that demand the United States Forest Service began testing structural timbers, even before the Forest Products Laboratory was established. The timbers tested were graded by five different sets of rules in use at that time. The results of the tests indicated that "the rules were not effective in separating structural timbers according to their strength" *(1, 2)*. They were either too restrictive or too general and the position in the timber of those characteristics that influence the strength was not considered. An attempt was therefore made to formulate a set of definitions and specifications applicable to all species that would more efficiently separate structural timbers in accordance with their strength.

No attempt was made to establish working stresses for species or grades. The values obtained from each individual structural timber test, together with the average, maximum, and minimum values for species and average values from the small, clear specimens cut from the structural timbers were published in 1912 *(1, 2)*. The engineers, architects, designers, or code authorities had to determine their own working stresses from the published data.

Ten years later, after the Forest Service had established the Forest Products Laboratory at Madison, Wis., there was a continuing demand on the Laboratory to recommend working stresses. The commercial grades still did not specifically limit knots and other characteristics from the strength standpoint, and it was impractical to assign efficient working stresses to such grades. It was not practical to test all the commercial grades of the various species because of the expense of the vast amount of testing that would be required and because of the continually changing character of the material admitted under grades with only general strength limitations. A set of basic grading rules to which working stresses could be assigned was therefore prepared and published *(3)* by the Forest Products Laboratory in 1923. These grades were applicable to all species.

The basic stresses for clear timbers were determined by applying a reduction factor to strength values obtained from tests of small, clear, green specimens. The reduction factor provided for the variability of the material, the effect of long-time loading, and a factor of safety. Working stresses for the grades were then obtained by applying a factor to the basic stresses to take care of the knots and other growth characteristics that affect the strength. That factor was obtained from an analysis of tests of structural timbers. It varied with the grade and was called the grade ratio. The grade ratios for the basic grades designated S1, S2, S3, and S4 were 87½, 75, 66⅔, and 50 percent, respectively. In other words, the basic grades were designed to limit knots and other characteristics so as to assure that any timber depending on the grade would develop at least ⅞, ¾, ⅔, or ½ of the strength of the basic clear wood stress.

American Lumber Standards in 1925 *(4)* issued "Basic Provisions for Selection and Inspection of Softwood Dimension and Timber Where Working Stresses Are Required." Those provisions used two of the basic grades, S2 and S3, as examples for use by lumber manufacturers in the preparation of commercial grading rules for structural material.

The regional lumber associations that produced the bulk of the structural lumber prepared grading rules conforming to the principles set forth in American Lumber Standards *(4)*. The lumber associations, however, experienced difficulty in evaluating their grades since neither of the publications cited *(3, 4)* showed how to describe other grades or to determine appropriate working stresses for them. The Forest Products Laboratory, therefore, prepared Miscellaneous Publication No. 185 "Guide to the Grading of Structural Timbers and the Determination of Working Stresses" *(5)* to present a generalized system for specifying the features that affect the strength of timber together with a procedure for determining working stresses appropriate to any grade. The system presented was based on the same principles of grading as American Lumber Standards and in 1939 was made a part of those standards by reference.

The basic stresses, which were presented in Miscellaneous Publication No. 295 *(3)* and Miscellaneous Publication No. 185 *(5)*, remained unchanged over a period of 20 years. During that period they were adopted by A. S. T. M., A. R. E. A., the lumber industry, and code authorities throughout the United States. The stresses recommended in them became the generally accepted basis for design of timber structures. They proved to be safe and the only criticism made of them was that they were conservative.

The shortage of lumber that developed in World War II resulted in an increase in working stresses to conserve critical material. A 20 percent increase was put into effect by the War Production Board in their Directive No. 29 *(6)*. Directive 29 was mandatory but applied only to stress-grade lumber used in buildings. The Army, on theater of operation structures, increased stresses as much as 85 percent over those commonly used. Upon the termination of hostilities, Directive 29 was withdrawn. The withdrawal of Directive 29 raised the question of the desirability of continuing the increased working stresses it had prescribed.

The National Lumber Manufacturers Association in 1944 issued the National Design Specification *(6)* continuing the 20 percent stress increases of Directive 29. The stresses were recommended not only for use in buildings but also for all timber structures. Meanwhile the Forest Products Laboratory and the lumber industry, through the National Lumber Manufacturers Association, started a re-examination of working stresses and stress grades in the light of the additional data obtained and the technical advance made in the 22 years that had lapsed since the working stresses and stress grades were first established on a scientific basis.

Re-examination of Working Stresses

The problems of evaluating working stresses was attacked from several angles. A study was made of the wartime buildings that had been designed and erected by Army and Navy using increased working stresses. All available data of the Forest Products Laboratory was reanalyzed, including the data used in establishing the first working stresses as well as data collected in the 22 years since they were first published. Conferences were held with consulting engineers, railroad engineers, university professors of engineering, and other engineers engaged in the design and erection of timber structures to obtain information on engineering practices and to obtain their aid in evaluating factors involving judgment, such as the true factor of safety. Conferences were held with the staff of the Forest Products Laboratory of Canada to coordinate data and studies obtained in both the United States and Canada. The Forest Products Laboratory of Canada also furnished detailed data on the results of 2,500 tests that they had made on structural timbers.

The study of wartime wood construction erected by the Army, Navy, and civilian agencies was made to determine the service rendered by buildings designed on the basis of increased stresses. The buildings erected by the Army alone on this continent were equivalent to one building 70 feet wide reaching from New York to San Francisco. The Army cooperated in the study by furnishing inspection

reports on the condition of that enormous amount of wood buildings.

Analysis of the Army reports, together with the inspections made of Navy and civilian buildings indicates that information obtained from the failure of structural members of buildings in service is not specific enough to serve as a basis for working stress recommendations. The analysis did show that the principal causes of failures were the use of green lumber without appropriate design details, lumber of lower quality than the designer anticipated, poor fabrication, and poor design. There was no evidence in any of the reports or inspections of hundreds of buildings to show that any timber of structural grade did not or could not safely sustain the recommended working stresses. A considerable number of the Army and Navy wood buildings had clear spans in excess of 100 feet and some well in excess of 200 feet. When various factors are considered, the working stresses for the lumber in many war buildings exceeded 1½ times those recommended for prewar construction. Nevertheless, up to June 1948 there were only four cases where a truss or larger portion of a structure collapsed in Army buildings, all four of which can be attributed to faulty design or construction practice rather than to the design stresses for the grade of lumber used.

The reanalysis of the data of the Forest Products Laboratory and the analysis of the data furnished by the Forest Products Laboratory of Canada were made to check the items in the reduction factor used in obtaining the basic stresses from values obtained from tests of small, clear specimens. The reanalysis of data from small, clear specimens and the analysis of data on structural timbers checked the ¾ factor originally used for variability. The study of a large amount of data on the effect of duration of load obtained since the working stresses were originally established indicated that the $\frac{9}{16}$ factor for long continued loading, used originally in obtaining basic stresses, was about correct. It appeared, however, that when the maximum design load would not be on timber continuously higher stresses than those recommended could be used. Provision was therefore made for increasing the allowable stresses when the period during which the actual loading on the element produces the stress induced by full maximum design load is 3 years or less.

A further factor of 3/5 was used to take care of a number of other items. Among them were slight errors in design, design tolerance, off-grade, undersize, and overloading. An attempt was made to evaluate these. They, however, vary widely and the amount necessary to provide for them is a matter of engineering judgment. A consensus of opinion of engineers was obtained by conferences, interviews, correspondence, and questionnaires. That study reemphasized that working stresses for wood, like those for other materials, involve engineering judgment and hence cannot be arrived at by any mathematical analysis alone.

The average value from laboratory tests multiplied by ¾ for variability, $\frac{9}{16}$ for duration of load, and 3/5 for other items gives a basic stress about ¼ of the laboratory test average. This factor of 4 between test result and basic stress is sometimes erroneously called the factor of safety. It should be clearly understood that loading to 4 times the design load is not a safe procedure, since much of the factor of 4 is required to convert from the conditions of test to the conditions of service.

Present Recommendations

In making the revised recommendation for working stresses, the following basic principles were assumed:

a. Competent design
b. Good fabrication
c. Reliable grading
d. Adequate supervision
e. Adequate consideration for variability
f. Long-time service at maximum design load
g. Adjustment of stresses for other durations of loading
h. A reasonable factor of safety

The revised recommendation for basic stresses provided for a 10 percent increase in basic stresses for bending and horizontal shear, for increases in all properties except modulus of elasticity when the total cumulative time the load will be on structures is less than 30 years, and for adjustments of working stresses for commercial grades for drying, density, and close grain.

As soon as the findings from the Forest Products Laboratory re-evaluation of basic stresses became available last June, the Technical Advisory Committee of the National Lumber Manufacturers Association and other timber engineers met with the staff of the Forest Products Laboratory to revise the National Design Specification *(6)* to bring it into conformance with the latest available technical findings. Also, commercial stress-grading rules were revised to reflect these data.

Initially, these design recommendations were developed under the sponsorship of the War Production Board with the cooperation of the Forest Products Laboratory, the National Lumber Manufacturers Association, government design agencies, and many other qualified groups and individuals. They were issued as mandatory specifications by the War Production Board in August 1943. After some revision to incorporate additional findings and to adapt the wartime specification to peacetime application, the National Lumber Manufacturers Association approved in December 1944 and published in June 1945 "National Design Specification for Stress-Grade Lumber and Its Fastenings" to become effective upon revocation of War Production Board Directive No. 29. In whole, or in part, the recommendations therein are incorporated by reference or otherwise in the current editions or new drafts of all the major standard uniform building codes, several recent standards of the American Standards Association, practically all city building codes recently adopted, and in drafts of most of the codes under consideration by city authorities. In many other cases where not actually included in the code, it is being used as a reference by city building officials. Likewise, major government design agencies have adopted the recommendations and the specification is used as student text or reference by most of the major engineering schools of the country.

One of the important recent improvements in timber design practices has resulted from more accurate information obtained by the Forest Products Laboratory on the effect of duration of loading on strength of wood. The findings are reported in "Recommendations for Basic Stresses" *(8)*. The information permits designers to use with greater confidence and efficiency the remarkable property that wood has of being able to support much greater loads for short durations than for long durations. The type of maximum loads on most structures are of the shorter durations rather than full maximum loads for the life of the structure. In the National Design Specification, which recognizes this situation, the stress values therein are presented to fit the bulk of design conditions with recommended adjustments of design stresses for permanent application of maximum load and other conditions of loading. However, the basic stresses developed by the Forest Products Laboratory, which have many applications other than to stress-graded lumber and structural design, are presented on the basis of maximum loading permanently applied with adjustments for other conditions of loading. Both publications are fundamentally in accord, but there are some differences in presentation of which this is one.

Progress in Timber Construction

In summary, great technical advances in timber engineering have been and are being made in the structural field. This leads to more economical and adequate wood structures. One fabricator estimated that application of recent improved design recommendations resulted in a cost saving in the structural framework of about 15 percent. Wood continues to be recognized as a major engineering material and it is taking many construction jobs away from competing materials.

As in all fields, there are many investigations in the lumber construction field that should be made to permit further progress. With increased application of increasing technical knowledge, more economical and satisfactory wood structures result. Approximately two-thirds of the lumber produced in this country goes into construction in one form or another. Intelligent research in this field pays large dividends.

Literature Cited

(1) Properties and Uses of Douglas-fir, by McGarvey Cline and J. B. Knapp. U. S. Dept. Agr. Forest Service Bull. 88. 1911.
(2) Tests of Structural Timbers, by McGarvey Cline and A. L. Heim. U. S. Dept. Agr. Forest Service Bull. 108. 1912.

(3) Basic Grading Rules and Working Stresses for Structural Timbers, by J. A. Newlin and R. P. A. Johnson. U. S. Dept. Agr. Department Circ. 295. October 1923.
(4) Elimination of Waste. Simplified Practice Lumber, issued by the Bureau of Standards, U. S. Dept. Commerce. 1925.
(5) Guide to the Grading of Structural Timbers and the Determination of Working Stresses, by T. R. C. Wilson. U. S. Dept. Agr. Misc. Publ. 185. February 1934.
(6) National Design Specification for Stress-Grade Lumber and Its Fastenings. Revised 1948. National Lumber Manufacturers Association.
(7) Supplement to U. S. Dept. Agr. Misc. Publ. 185. May 1940. U. S. Forest Products Laboratory Mimeograph R1225.
(8) Recommendations for Basic Stresses. Supplement No. 2 to U. S. Dept. Agr. Misc. Publ. 185. June 1948. U. S. Forest Products Laboratory Mimeograph R1715.

Discussion

Robert A. Cockrell (University of California): In connection with the use of structural grades of timber, particularly in light frame construction, isn't it possible to make further savings of material by having the man on the job better educated in the proper placement of knots and other grain irregularities to get maximum structural efficiency? Certainly there is always the lower limit of the grade to contend with in use and that certainly requires judgment. If wood workers generally had an appreciation of the behavior of wood in structures, it might even be possible to lower the limits for the grades and thereby get a more complete utilization of wood.

Mr. Hanrahan: Professor Cockrell's suggestion, that if construction men would place the knots and other irregularities so as to get maximum structural efficiency, a saving in material could be made, is correct theoretically. However, structural designers cannot assume that this will be done in every case on the job. Consequently, the practical approach is to limit in stress-grading rules the size and location of such characteristics to insure a given minimum strength for each piece of lumber.

It should be pointed out that for such buildings as houses ordinarily stress-graded lumber is not needed, i.e., yard grades of lumber are quite satisfactory. Where the frame is composed of so many closely spaced members, with covering on one or both sides, such as in wooden houses, the overstressing of a weak framing member does not result in a serious failure. Ordinarily, the load will be redistributed to stronger adjacent framing members. Even complete rupture of a single framing member does not result in collapse of the structure.

However, in large framed structures, where framing members are spaced many feet apart and carry very large loads without assistance from other members, rupture of a single piece is likely to cause collapse of at least a portion of the structure. Stress-grades are intended and designed primarily for such applications where each member must carry substantial loads without assistance. Consequently, these grades are made as foolproof as possible. No scientific knowledge of structural engineering and wood technology is assumed to be applied by the workman.

Serious obstacles stand in the way of training or supervising workmen to the extent of getting such required knowledge across to them and having them apply it religiously. Both the wood technology and engineering conceptions required are complex. They are not easily understood and applied by workmen. Further, the solution to the problem of actually getting workmen interested to the extent necessary to acquire the needed knowledge, and unerringly apply it in their daily work, is an almost impossible educational endeavor. The designer must be assured that each and every workman would do it, not just an occasional workman. Also, contractors are interested in rapidity of construction to keep their labor costs down. It is questionable whether the contractor would save enough in the cost of materials to offset the additional labor costs of applying such data. His biggest hope of making a profit is to reduce his labor operations to the simplest and most routine operations to get maximum production.

By the above, I do not mean that we should not attempt to train people toward better utilization of lumber. Many of the old-time carpenters who took real pride in their work had

an amazing knowledge of what wood would and would not do. Such training and education as may be practical would be quite helpful in overcoming the most obvious serious misuse of wood. Possibly the best means of getting such information across to the workmen would be through labor unions and apprentice training programs.

The lumber industry has made some training efforts in connection with the Retail Lumber Dealers' training courses, sponsored by the National Retail Lumber Dealers Association and State organizations of retail dealers, at various universities, and in connection with regular courses of instruction conducted by the universities. Also, publications recommending certain grades for each of various construction items have been published. However, to my knowledge, no attempt has been made to train all carpenters and other workmen in detailed grading of lumber on the job and in the engineering principles necessary to take advantage of the strength of individual pieces in an engineering design.

Frankly, I personally do not believe that it would be practical to depend on workmen on construction jobs to place knots and other irregularities so as to get maximum structural efficiency in a structure where stress-grades are needed. However, in fabricating plants, closely supervised by technical men, sorting of pieces within a grade before fabrication may prove a practical operation if a cost saving in the particular fabricated article can be demonstrated.

Mr. Johnson: Stress-grade lumber is seldom used in light construction. Professor Cockrell is therefore probably referring to the dimension grades of yard lumber. Dimension lumber is not graded in accordance with the principles of strength grading. The strength of dimension therefore varies widely. There is an opportunity for improved utilization in the selection and placement of yard lumber. The most practical way to improve selection is by grading dimension for strength. The Southern Pine Association and the West Coast Lumbermen's Association have, in their latest rule books, applied the principle of strength grading to No. 1 and No. 2 dimension.

The dimension grades have been used many years in construction despite the wide variations in the strength of lumber in them. The lack of interest in selection from, or strength grading of, dimension is due to the large proportion of dimension that is used where stiffness rather than strength controls. Defects have little effect on stiffness and selection for stiffness on the basis of the defects present is therefore not practical.

Selection could be used to advantage even in stress grade lumber. A knot on the compression face is only half as injurious as a similar knot on the tension face. A system of selection that would insure the worst knots being placed on the compression face would permit increases in stress from 10 to 15 percent. No satisfactory system to insure such placement has as yet been devised.

Consideration was given to marking stress grade lumber for placement. Observation of containers marked "This side up" resulted in that idea being abandoned. In too many instances the individual handling a package marked "This side up" either did not read it, could not read it, or paid no attention to it.

FOREST PRODUCTS RESEARCH SOCIETY

Some Problems in the Design and Performance of Laminated Wood Trusses

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This paper is a description of the design, construction, and performance under proof loading of a glued, laminated wooden arch of 47-foot span. The arch was designed for use in a wing of a proposed new testing laboratory and was constructed of white spruce glued with casein glue. It was then subjected to a continuous proof-loading test that continued for more than a year, during which time periodic readings of deflection were taken. The effect of temperature on the long-term strength of laminated arches is discussed.

Introduction

DURING the past 10 or 15 years there has been, in North America, a steadily growing interest in glued, laminated, wooden construction. This has been due, in part, to the extensive use of this type of construction in Europe, where glued, laminated beams and arches have been employed for about 30 years. It was greatly accelerated during World War II, when the United States and Canada were short of steel for building construction and it was necessary to find new methods of utilizing timber in construction.

A considerable number of buildings erected during the war employed such types of construction as glued, laminated beams, arches, and bow-string truss chords. Most of this work was done with a limited amount of information regarding the best methods of design, and with little experience on the part of the designing engineers. It was known that a properly made glue joint may be stronger than the wood itself, but most of the other factors involved were not familiar to the structural designer, who suddenly found himself faced with the problem of designing a structure involving a novel use of wood and a novel method of fastening it together.

The practicability of this type of construction is clearly indicated by the success with which these many buildings have performed the services for which they were intended. Although the stimulus of a steel shortage is not so acute as during the war period, laminated wood construction has won a place in the construction field on its own merits, particularly in those buildings or structures where special considerations such as size, span, or appearance are determining factors. It now remains to demonstrate to the architectural and engineering professions, and to the construction industry as a whole, what can be done in the way of glued, laminated, wooden construction and how it can best be accomplished.

Purpose of the Investigation

The Forest Products Laboratories of Canada have been actively interested in the technical aspects of glued, laminated wooden construction for a number of years. A considerable amount of basic research has been carried on to determine the strength, durability, and moisture resistance of various types of glue when used with woods of various species. In addition, some work has dealt particularly with the use of glue in laminated beams and arches.

This latter work has included an investigation into the strength properties of full-sized laminated beams, glued with two basic types of glue and assembled under both nail pressure and clamping pressure. A long-term experiment has also been undertaken which will yield, over a period of 10 years, valuable data concerning the durability of laminated beams when glued with three basic types of glue and then exposed to the weather continuously for varying periods of time.

The construction and testing of a large structural arch were considered to be important phases of the general investigation into the strength properties of glued, laminated construction. The arch selected for the test was designed by the author to suit the requirements of a particular type of building. The type is one which would be suitable for auditoriums, drill halls, recreation rooms, testing and re-

search laboratories, or any other use calling for large rooms with unobstructed floor space.

Method of Design

In designing the laminated arch, the requirements of the National Building Code[1] were adhered to in assuming probable roof loads. The working stresses in shear and flexure were chosen on the strength of data, assembled by the Laboratories, pertaining to the strength properties of white spruce of the grade to be employed.

The arch (Fig. 1) was designed to fit inside a building with an inside width of 47 feet 6 inches, a height, to underside of roof at the peak, of 21 feet 6 inches, and a wall height, to the underside of the roof, of 14 feet 3 inches. The spacing of the arches along the length of the building was 11 feet on centers.

The dead load of the roof was about 14 p.s.f. The assumed weight of the snow was 40 p.s.f. of the horizontally projected area. The arch was designed to support this total load with what was considered to be an ample margin of safety, allowing for the fact that the weight of the arch itself was not taken into consideration.

The shape and size of the arch was governed by certain practical considerations in addition to the loads which had to be supported. It was planned to use lumber with a nominal rough thickness of 1 inch and a dressed thickness of 7/8 inch or less. Since the degree of curvature that can be applied to a board is dependent upon the thickness, the minimum radius of curvature in the arch was adopted on the basis of a 7/8-inch lamination.

In a Tudor arch, it is desirable to keep the radius of curvature of the haunch to a minimum in order to conserve space. The radius that was finally adopted was 87.5 inches, which is exactly 100 times the thickness of the assumed 7/8-inch lamination. The initial stresses set up in the first lamination to be bent around the form were quite high, as can be shown by a theoretical consideration of the factors involved.

The average modulus of elasticity of clear, air-dry, Canadian white spruce is 1,390,000 p.s.i. Therefore, a board 7/8-inch thick, bent around a form 87.5 inches in radius, will develop a computed stress of 6,900 p.s.i. A consideration of the strength values obtained from bending tests on clear air-dry spruce will show that this stress is far in excess of the average fiber stress at proportional limit of 5,200 p.s.i. and is, therefore, unobtainable by the degree of bending applied. When the proportional limit of the material has been passed, the modulus of elasticity begins to fall off; it must be assumed, therefore, that the stress induced in the first lamination by its initial bending must have been in excess of 5,200 p.s.i. but less than 6,900 p.s.i. It is also interesting to note that the average modulus of rupture of clear air-dry Canadian white spruce is 8,700 p.s.i., a figure which is not comfortably above the theoretical figure of 6,900 p.s.i.

The haunch, or curved portion of the arch adjacent to the eaves, was of uniform cross-section. The depth of the arch varied from a maximum at the haunch to a minimum at the crown and support hinges and was governed by the requirements of bending and longitudinal shear at any section.

The width of the arch rib was 11 inches throughout. Eleven inches was chosen because it provided a depth-width ratio at the haunch of about 2 to 1, a figure that combines both efficiency and torsional rigidity and because it allowed of shallow depths at the crown and support points, thereby providing a satisfactory "hinge-effect". The 11-inch width of the arch rib was obtained by using 3½-, 5½-, and 7½-inch boards, in an overlapping pattern in each succeeding layer in the arch.

The final design called for an arch rib 11 inches wide, 25⅜ inches deep at the haunch, and 10½ inches deep at the crown and support points. These dimensions gave calculated stresses of about 700 p.s.i. in bending at the haunch and about 100 p.s.i. in shear at the supports under full dead and assumed snow load, but neglecting the weight of the arch itself.

Construction

The arch was constructed by the staff of the Laboratory. The lumber used was commercial white spruce of select merchantable and merchantable grades. The glue was a good com-

[1] Published by the National Research Council, Ottawa, Canada.

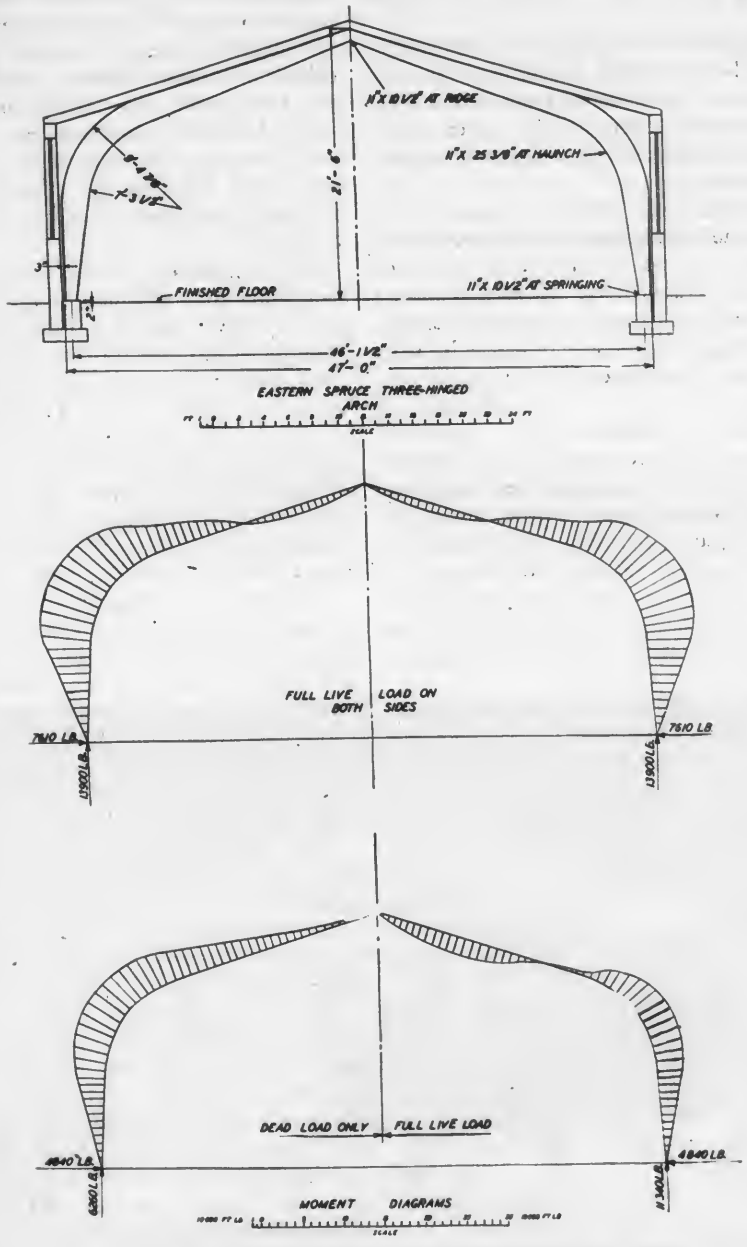

Fig. 1.—Design drawings of 47-foot laminated arch.

mercial grade of casein. The means of applying gluing pressure consisted mainly of 2-inch nails.

White spruce was chosen because it was believed to be particularly suitable for this type of construction in moderate spans and also because laminated arches of certain other species had been constructed and used in quite appreciable numbers.

Casein glue was selected because of its known durability under dry conditions such as would obtain in a heated building, its ease of mixing and because it can be used on wood with a fairly wide range of moisture content.

The gluing pressure was provided by nails in order to demonstrate the ultimate in simplicity of construction. Few woodworking shops would be without sufficient equipment to build a laminated arch by this method. Clamping pressure has always been considered better than nailing pressure because it provides greater unit gluing pressure, resulting in thinner glue lines. It was intended to demonstrate, however, that sufficient glue-line strength can be achieved by nailing, and that clamping pressure, though admittedly the better method, was not necessary in this instance.

The lumber was purchased in random lengths of 12, 14, 16, and 18 feet; the few 18-foot lengths were reserved for the outside tension face of the arch. The greater part of the material was of poor or medium quality. The best grades were reserved for the highly stressed regions in the outer sixth of the arch and for the curved portion of the haunch. The lower grades were used in the interior portions where the stresses in tension and compression were quite low.

Before a lamination was installed in the arch, the lumber was end-glued to make up length equal to the perimeter of one-half of the arch. These end joints were effected by the use of 1 in 12 plain-tapered scarfs, which were glued together, several laminations at a time, in a screw press.

As pointed out in the theoretical considerations of the initial stresses developed in the laminations during bending to the curvature of the arch, the computed stresses were in excess of the average elastic limit of clear white spruce and were not far below the average modulus of rupture of clear specimens of this species. Allowing about 25 per cent for the natural variability of the species and taking into consideration the fact that the material used was not absolutely clear or straight-grained, it is evident that some difficulty might be experienced in bending the laminations around the form. Attempts at bending the wood in the cold state were generally unsuccessful, and it was found that only the relatively clear and straight-grained material would bend without breaking.

It was necessary, therefore, to subject each lamination to a steaming treatment before it was bent over the form. Several laminations were placed in a narrow box about 8 feet long with slots in the ends and a closely fitting cover. Live steam was piped into this box for a period of 1 to 2 hours, after which the laminae were removed from the box and immediately bent over the form. Care was taken to insure that the casein-glued scarfed joints were outside and some distance from the box, where they would be unaffected by the steaming.

The form was constructed to the contours of the inside face of the half-arch. It was erected on the floor of a shed and was carefully aligned and rigidly braced. As the laminations were added to the arch, glue was spread on both gluing faces and on the abutting interior edges by means of brushes. The boards were then placed quickly on the form and nailed firmly to the preceding laminations.

Two rows of 2-inch common bright steel wire nails were used in each board, or four rows in the width of the arch rib. The nails were spaced at intervals of about 6 inches along each row, and the rows themselves were spaced about 1 inch from the edge of each board.

The first (inner) seven laminations were full-length, running from footing to crown hinge. Starting with the eighth lamination, however, each successive piece was made slightly shorter than the previous one, until 20 such pieces had been applied, the last being of such a length that it completely traversed the haunch of the arch, running out at the tangent points. This procedure was adopted because the design, for structural reasons, called for a considerably greater depth at the haunch than at the footing or the crown hinge. The stepped surface was then planed down to two straight surfaces tangent to the curve of the arch, and

construction was completed by applying to the outer face eight full-length laminations from footing to crown hinge. When the glue had set, the arch was planed and sanded to a smooth finish, the ends were trimmed off to the proper angle, and the entire structure was given a coat of lead paint to protect it from rain during erection.

Crown Hinge

Although the arch was three-hinged in design, no provision was made to install frictionless pins at the three hinges. The arch was intended to be carried on flat footings and the lower end of each section was therefore cut off square; the top ends were cut off at an angle such that the arch would abut at the crown along a vertical plane.

The halves of the arch were joined at the crown hinge by a simple sleeve welded from 3/8-inch steel plate. This was made to fit tightly at the sides, but loosely at top and bottom, to allow for deflection under test loading.

Erection

The arch was erected outdoors, as there was insufficient head room in any of the buildings of the Laboratory. It was erected under four timber bents, each bent consisting of a pair of 6-inch square verticals capped with 6- by 10-inch timbers. The bents were rigidly X-braced to prevent the arch from deviating from the vertical plane during testing.

The arch was supported on spread footings, which rested on a foundation of clay covered by about 5 feet of fill. The footings consisted of four railway ties, each 8 feet long, 9 inches wide, and 7 inches thick, bridged by two 7- by 9-inch timbers on edge.

The horizontal thrust of the arch at the supports was taken by two 7/8-inch round steel rods fastened by nuts and washers to a pair of 3-inch steel channels at each end.

Testing

The load was applied by the use of eight large wooden boxes (Fig. 2), each capable of holding 64 cubic feet of sand. The boxes were supported from the top surface of the arch by means of half-inch steel rods uniformly spaced along the span of the arch. In order to prevent a serious accident to the workmen loading the arch, two rows of timbers were placed on

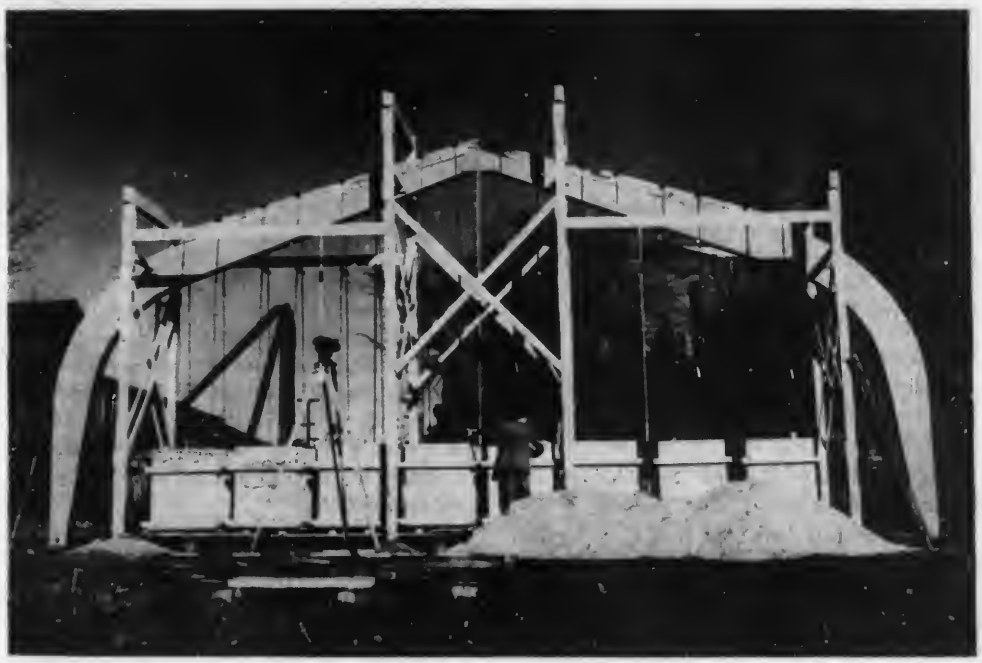

Fig. 2.—47-foot laminated arch undergoing test.

the ground beneath the boxes, with a scant two-inch clearance between the boxes and the timbers. If a sudden failure had occurred during loading, the arch would have been completely relieved of load after a deflection of 2 inches. As normal deflection progressed during loading, the safety timbers were adjusted to maintain adequate clearance beneath the boxes.

At regular intervals during the loading operation, deflection readings were taken at three places on the arch—at the crown hinge and at points about 10 feet on either side of the crown hinge. Readings were also taken of the settlement of the footings in relation to an established level.

The calculated dead load of the roof was slightly under 7,400 pounds. The loading apparatus itself weighed nearly 3,800 pounds. It was necessary, therefore, to add 450 pounds of sand to each box to obtain a condition equal to dead loading only. The sand was added to each box in increments of 100 pounds and deflection readings were taken after each increment had been added.

After the dead load had been applied, the "snow load" was applied to one-half of the arch only. The load was applied to the north half of the arch in increments of 200 pounds per box until the four boxes each contained 3,000 pounds of sand. As would be expected, the north quarter-point deflected considerably more than the south quarter-point under this eccentric loading.

The full "snow load" was then applied to the south half-arch in increments of 200 pounds per box. Under conditions of full dead and full snow load over the whole arch, the following conditions were observed:

Vertical deflection of crown hinge	1.51 inches
" " " north quarter-point	0.90 "
" " " south quarter-point	0.80 "
Total horizontal deflection 7 feet above footings	1.00 "

The total superimposed load under the above conditions was 27,800 pounds.

After the full live load had been applied to the whole arch, the overload was applied in increments of 100 pounds per box in each of the eight boxes. This loading procedure was continued until each box contained 5,600 pounds of sand, giving a total applied load of 48,600 pounds. This load is equivalent to the following:

Dead load of roof	14 pounds per sq. ft.
Snow load on roof	40 " " " "
Overload	40 " " " "

Under conditions of overload, the following readings of deflection were obtained:

Vertical deflection of crown hinge	2.59 inches
" " " north quarter-point	1.49 "
" " " south quarter-point	1.40 "
Total horizontal deflection 7 feet above footings	1⅔ "

During the whole of the loading process, the arch behaved very well and showed no sign whatever of incipient failure. However, one of the inherent characteristics of wood is its ability to withstand very heavy loads of short duration. This is a desirable quality, since structures are sometimes called upon to withstand loads greatly in excess of those contemplated in the design. These loads include accidental overloads caused by human error, earthquake and hurricane loads, and freak snowfalls.

It was decided, therefore, to leave the arch under overload for a period of several months and to continue the observations of deflection in order to determine whether the arch was capable of supporting the load on a long-term basis. Accordingly, the arch was left under overload for the remainder of the winter and readings of deflection were taken at intervals of about 1 week.

It must be recognized that the conditions under which the arch was subjected to test were not by any means ideal. The arch had been designed and constructed on the assumption that it would be used in the interior of a heated building, protected from rain, high humidity and extremes of temperature. The actual test conditions involved the exposure of the arch to wind-driven rain, to considerable variations in relative humidity and to extreme variations in temperature as afforded by the Canadian climate.

Although the arch had been given three coats of lead paint before testing, it must be assumed that some change in moisture content would take place from week to week and from season to season. An increase in moisture content would result in two things, a weakening of the

wood fibres and an increase in the width and depth of the arch rib. This increase in depth, occurring at the haunch or curved portion would result in an increase in the radius of curvature of the haunch. Similarly, a decrease in moisture content would result in a decrease in the depth and a decrease in the radius of curvature.

The effect of temperature would be somewhat similar to the effect of change in moisture content. A decrease in temperature would result in a strengthening of the wood fibers and also in a decrease in the width and depth of the arch rib. This decrease in depth, where it occurred at the haunch, would result in a decrease in the radius of curvature as well as a decrease in the section modulus and moment of inertia of the cross-section. An increase in temperature would result in a reversal of the above conditions.

The coefficient of thermal expansion of wood is very small and it is not claimed to have had any appreciable effect on the behaviour of the arch. The effect of temperature on the strength of the wood fibers, however, is thought to have had a considerable effect on the test results.

Work done by P. H. Sulzberger of the Australian Forest Products Laboratory indicates that temperature is a critical factor affecting the strength of wood. Sitka spruce, for example, tested at 14 per cent moisture content, was found to have a modulus of rupture of 14,940 p.s.i. at –20° C. (–4°F.), 13,670 p.s.i. at 0° C. (32° F.) and 11,940 p.s.i. at 20° C. (68° F.). These figures indicate that, over the range tested, the strength of wood in bending might vary by one percent for each 2.9° F. change in temperature. Moreover, it was also found that the rate of strength decrease would increase as the temperature rose above ordinary room temperatures.

The temperatures encountered during the time that the arch was under load had a range of more than 100° F. Such a large range of temperatures would doubtless have an appreciable effect on the test results, particularly when the structure was in the overloaded condition.

The horizontal thrust at the footings of the arch was restrained by a pair of ⅞-inch steel tie rods. It is suspected that the variation in temperature would also have an effect on these rods. When the temperature rose, the steel rods would lengthen, owing to thermal expansion, and the arch would slip slightly on its footings. When the temperature dropped, the steel rods would tend to tighten up again but would not have sufficient strength to overcome the friction between the arch and the footing in addition to the horizontal thrust caused by the load on the arch. This theory is suggested as a possible explanation of the fact that the out-to-out span at the base of the arch increased by ⅛ inch from November, 1947 to May, 1948. It is calculated that this slipping of the arch at the footings would cause an apparent, but not real, deflection of 0.07 inch at the crown hinge.

It is evident, therefore, that exposing the arch to varying climatic conditions during the period under test must necessarily have brought into the picture certain variables which are difficult, if not impossible, to evaluate and that the results cannot be regarded as possessing the same degree of accuracy as if the arch had been tested in a chamber with controlled temperature and relative humidity.

Behaviour Under Constant Load

The arch had been loaded with a dead weight of 48,000 pounds on November 3, 1947. This load was left on the arch until May 19, 1948. During this period, deflection readings were taken, from time to time, to record the changes that were taking place. A graph (Fig. 3) was then prepared which relates the deflection of the crown hinge with the time that the arch was under load.

Immediately after the arch had been loaded, the deflection of the crown hinge was found to be 2.59 inches. The deflection continued to increase, however, until early in December. It is interesting to note that the rate of increase of deflection decreased as the mean daily temperatures decreased, until about mid-December when cold, wintry weather firmly established itself in the Ottawa area.

The deflection of the crown hinge remained constant from about mid-December until about mid-March. An examination of the temperature graph will show that spring weather began to make an appearance at about the middle of

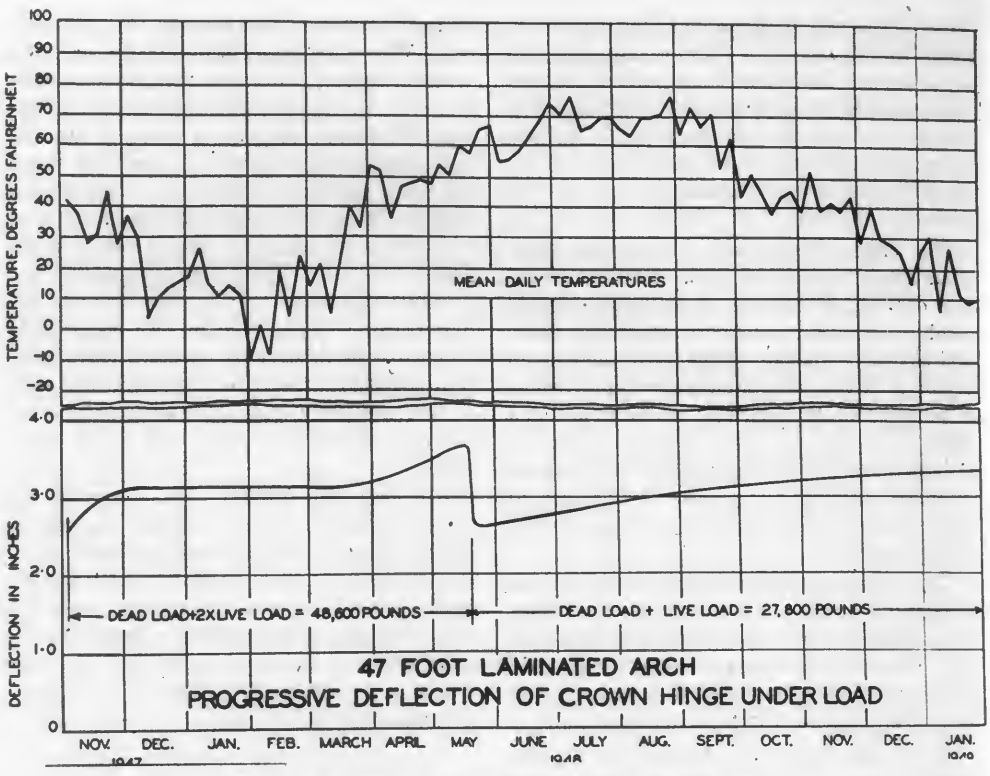

Fig. 3.—Progressive deflection of crown hinge under load.

March. Coincident with this trend toward higher temperatures, the deflection of the arch also began to increase. The rate of increase of deflection increased from about mid-March until about the middle of May, during which period the daily mean temperature showed a steady increase. This prompted the decision to remove the excess load of 20,800 pounds and to leave the design load only (27,800 pounds) on the arch for the remainder of the summer.

As the overload of 20,800 pounds was removed, the arch recovered some of its deflection. However, the recovery during removal of this load did not quite equal the deflection that had taken place during the initial loading of the arch with the same overload. The full design load (dead load plus snow load) of 27,800 pounds was left on the arch during the remainder of 1948 and into the early part of 1949. The time-deflection graph shows that the deflection under design load continued to increase. It should be noted, however, that the rate of increase throughout the summer of 1948 was much lower than the rate of increase during November of 1947. In the one case, cool weather and overload combined to give a high rate of increase and in the other case, hot weather and design load only gave a lower rate of increase.

Cooler weather prevailed in Ottawa from about the end of August, 1948, on into the winter. It will be seen that the deflection trends were similar to those of the previous fall and winter. As the temperature decreased, the rate of increase of deflection also decreased until, by about December, 1948, the deflection was again a practically fixed amount.

Conclusions

It appeared, from the results of this experiment, that temperature was one of the main factors influencing the deflection of the arch. The arch appeared to be overloaded under a continuous load of 48,600 pounds unless the

temperature was well below the freezing point of water. The arch was overloaded also under a continuous load of 27,800 pounds when the temperature was above 50° F.

The maximum flexural stress in the arch under full design load, was about 700 p.s.i. This is a very conservative design stress for white spruce under ordinary conditions, but apparently is too high for this particular application. One assumption is that greater allowance should have been made for the initial stresses set up in the laminations when they were bent around the form. These initial stresses, exceeding as they did the proportional limit of the material, were increased unduly by the addition of another 700 p.s.i. This brought the total stress to a figure within the plastic range of the material with the result that slow, continued deformation took place.

The arch could have been strengthened either by deepening the section or by employing thinner laminations. From the standpoint of appearance, and possibly also from the standpoint of economy, although this latter is doubtful, it would have been preferable to employ thinner laminations. The stress induced in the thinner laminations by bending around the form would have been much less and the capacity for taking additional stress would have been increased correspondingly.

It should not be inferred from this paper that the arch would have failed in service if it had been used in a building according to the design assumptions. The writer believes that the arch would have performed satisfactorily in ordinary service and that the reduced margin of safety might never have been detected. In this connection it should be remembered that the arch was designed for 14 pounds dead load and 40 pounds snow load on every square foot of the projected roof area. The snow load of 40 p.s.f. is seldom encountered even in Canada and ought to be considered a rare occurrence (say once in 10 years) rather than a continual happening. Moreover, such a freak snowload would probably not remain on the roof for the duration of the winter, but would be likely to be considerably dispersed by wind, evaporation, and thawing within two or three weeks.

Under normal conditions, therefore, the arch would be called upon to support the dead load only for the greater percentage of the year, a small snow load for two or three months of the year, and a maximum snowload for about one-half of one percent of the life of the arch. The writer believes that the arch would have been adequate under these conditions.

Discussion

Frank J. Hanrahan (National Lumber Manufacturers Association): Mr. Kennedy is to be complimented on his excellent paper and his most interesting investigation of the glued laminated arch. There are some factors which might have influenced the behavior of the arch, upon which Mr. Kennedy has not commented in his paper.

In the design of the arch, were the design stresses adjusted for depth factor? T. R. C. Wilson (U. S. Forest Products Laboratory) in "The Glued Laminated Wooden Arch", recommends that in design the sum of the combined bending and compression stresses should not exceed the allowable stress multiplied by the following depth factor:

$$1.07 - 0.07\sqrt{\frac{h}{2}}$$

where "h" is the depth of member in inches at the point under consideration. At the haunch of this particular arch, which is 23⅜ inches deep, adjustment for depth factor results in a reduction of about 18 percent in the allowable design stress.

Likewise, Mr. Wilson recommends adjustment of the design stress at the curved portion of the arch, in accordance with the following multiplying factor:

$$1.00 - 2000\left(\frac{t}{R}\right)^2$$

where $\frac{t}{R}$ is the thickness of lamination divided by the radius to which the lamination is bent. For ⅞-inch laminations bent to a radius of 87.5 inches, this gives a further reduction of 20 percent in the allowable stress at the haunch.

The preceding curvature adjustment contemplates bending and gluing at room temperatures and humidities. Steaming is known to weaken wood substantially. Has the author any data which would give an indication of the reduction in strength to be expected from

steam bending instead of room temperature bending?

The paper appears to be a progress report in that apparently the arch has not been tested to destruction. As additional information, it would be interesting to know the extent of any delamination of the casein glued arch under such exterior exposure. Also the extent to which extenders were used in the casein glue.

Any tests of matched samples from low stressed portions of the exposed arch and from an extension of the arch not subjected to exterior exposure but kept inside a building, which would indicate the relative performance and strength differences to be expected through inside and exterior exposures of casein glued arches, would be of interest.

Also, any auxiliary tests which would demonstrate the quantitative difference in performance and strength to be anticipated from nailed and clamping pressure assemblies would be helpful to designers. For example, T. R. C. Wilson, in his publication, recommends that, when the member is assembled by nail pressure gluing, the allowable stress in longitudinal shear should not exceed two-thirds of the value for a member assembled by clamp pressure gluing.

It is, of course, realized that there is a limit to the amount of investigation which can be undertaken in a given project. Mr. Kennedy is to be congratulated on his contribution. It is hoped that he will make further contributions to knowledge of the subject.

Mr. Kennedy: In reply to Mr. Hanrahan's question regarding the computation of strength reduction factors to take into account the depth of the arch rib and the bending of the laminations, I did not specifically refer to these in my paper because they were estimated rather than calculated. In other words, the arch was not designed with extreme precision because it was believed that the unknown factors in the design might make any attempt at such precision appear ludicrous. The arch was designed by cut-and-try procedures and, when a trial design gave calculated, uncorrected stresses of approximately 700 p.s.i., the design was accepted in the belief that such conservative stresses would take care of all likely contingencies. In any event, a safe working stress for select merchantable spruce of 1100 p.s.i., when reduced by 38 percent, gives a corrected working stress of nearly 700 p.s.i.

I have no data on the reduction in the strength of wood caused by steam bending, except what might be obtained from outside sources. It should be pointed out, however, that steam bending was not planned originally in the construction of the arch and therefore no correction for strength reduction was made in the design. Steam bending was resorted to only after it became apparent that cold bending of the particular grades of white spruce employed was impracticable. Rather than change the design and rebuild the form, the construction was carried on according to the original plans.

The arch has been tested to destruction since this paper was presented in May. A system of hydraulic cylinders connected to earth anchors was employed to apply the destructive load. The points of application of load (16 in number) were the same as were employed to support the 8 sand boxes. The arch failed in longitudinal shear at the south footing under a maximum load of 129,000 pounds. This was considered to be a very satisfactory proof of the adequacy of the design, especially in view of the fact that the arch had been subjected to continuous dead loading for so long a period prior to the destructive test.

The delamination of the arch during the period of exposure was superficial only and might be considered negligible. Perhaps a half dozen small cracks were visible at the time of the destructive loading test. I would like to emphasize, however, that the arch had been given three coats of paint and, in addition, a makeshift watershed was built above the arch to provide protection from direct rainfall.

No extenders were used in the casein glue.

The tests of matched samples and other auxiliary tests to which Mr. Hanrahan refers were not carried out because, as he points out, there is a limit to the amount of investigation which can be undertaken in a given project. Since nails were used to provide gluing pressure, the cutting of small test specimens from the broken arch was considered to be too hazardous an undertaking.

The arch failed in shear and there was evidence of some glue failure as well as wood failure. Most of the glue failure appeared to be the result of insufficient pressure in certain

areas. However, the author is inclined to the opinion that perfect gluing on every square inch of glued joint is not absolutely necessary on such a large member. In other words, the average strength of any one joint is of greater consequence than the strength of the weakest square inch of glue line. This theory is borne out to some extent by the results of the test. If the gluing had been much better than it was, it could not have increased the strength of the arch by an appreciable amount.

James F. Hamilton (Perkins Glue Company): What experiences in Europe have been had with casein glue?

Mr. Kennedy: It can be said that the Europeans have had considerable experience with casein glue used for gluing structural members. This experience extends over more than a quarter of a century and has given proof of the durability of casein glue under dry conditions. No other glue has such a long record of service in heavy timber construction and this is one of the reasons that casein was chosen for use in the 47-foot laminated arch. If the arch had been designed for exterior use, some other glue would have been selected rather than casein.

Axel V. Pederson (Economy Farm Structures): In Torebods, Sweden, nailing is used in connection with the core of arches. Flanges on the arches are formed by use of clamps in order to get proper strength in the glue line.

Glued Laminated Wood

Verne Ketchum

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The handicap of high cost of glued timber construction may be offset in whole or part by the use of higher stresses, and by elimination of costly ceilings, coverings, boxing enclosures, and servicing operations. Every advantage of glued construction must be used if it is to take its rightful place in timber construction.

Introduction

GLUED laminated structural members are today extensively used in timber construction and every indication points to increasing demands. With this new timber art we may now make curved members and bring to timber the beauty of the rainbow and the strength of the arch.

Now we may construct buildings with curved roofs, gothic barns, and churches with beautiful exposed wood arches that rest and delight the eye while lifting skyward the chapel roof. Timber can now be fashioned into strong compact truss chords curved or straight for buildings or bridges and into moulded boat frames. Members may be fashioned into tapered shapes which conform to varying stresses.

Laminating permits the selection of material in a member to place high strength and good appearance where strength and looks are most needed and placement of less desirable materials in less critical positions.

Glued laminated members do not check or split in service nor require servicing operations. They permit the construction of large sizes and long lengths, use little hardware or ironwork for connections, and require a minimum of fabrication and assembly.

Glued construction does have the handicaps of high cost and restrictions of transportation. No laminator has been able to produce a glued product at solid timber costs. Belief exists that scrap and waste can be utilized in a glued member that by some strange alchemy becomes low in cost and high in strength. Good laminated members require good lumber and more of it, size for size, than solid sawn members.

To the lumber the laminator must add glue, plant, equipment, labor and supervision to attain a member that is only then equivalent to a mill-delivered stick. Fabrication, hardware, ironwork, transportation, assembly and erection must later be added in like quantities to either mill-delivered or shop formed timber.

Transportation clearances restrict shipment of large curved members and so designers and laminators are restricted in shop production of large pieces. Large boomerang arches are especially hard to design and build except for nearby sites. Long distance shipping of large members requires splices near the section of maximum bending moment that make members unsightly and cost prohibitive. Shipping restrictions account largely for preference of three- over two-hinged arches.

Glued laminated structural members which use water resistant casein glues are for protected construction where moisture content of the wood can never exceed 20 percent. For service conditions where moisture content may exceed 20 percent waterproof resin glues must be used.

Glued laminated members may now be given fireproof or preservative treatments and operations may be such that treatment is applied to laminations before gluing or to completed glued-up member.

Load Conditions

Extensive test programs have proven that the strength of wood, unlike that of some other building materials, varies with duration of load and that all strength properties except modulus of elasticity may with safety be varied accordingly *(8)*.

The following classifications are used in the determination and application of timber stresses.

Long Time Service at Maximum Design Load

This type of loading applies to those structural members that must carry maximum design

load and consequently are fully stressed to maximum allowable stress for many years either continuously or cumulatively. Such load conditions would be encountered by timber members of rock cribs, dams, or retaining walls.

The Forest Products Laboratory uses this load condition for determination of basic stresses and values given in *(5)*. Stresses for this type of loading are considered to be about ten percent less than for normal loading (Table 1).

Normal Loading

Nearly all timber members in structures are never or at least only for comparatively short periods loaded to full design capacity. Assignment of working stresses is then made on this basis. Table 1 in National Design Specifications *(7)* gives working unit stresses for American Commercial Woods when used under normal loading conditions.

Two Months as for Snow

This type of load condition applies to members subject to snow loads. Stress values may be increased 15 percent for such loading over those permitted for normal loading.

Seven Days Duration

This load condition applies to those members which are fully loaded for a very short time and for a time which is much less than for snow conditions. Stress values may be increased 25 percent for such loading over those permitted for normal loading.

Wind or Earthquake

This load condition applies to those members which are fully loaded by wind or earthquake. Stress values may be increased 33⅓ percent for such loading over those permitted for normal loading.

Impact

This load condition applies to those members which are fully stressed by impact. Stress values may be increased 100 percent for such loading over those permitted for normal loading.

Increases apply to all stresses except modulus of elasticity. Percentages are not cumulative nor shall resulting member be smaller, nor shall fastenings be less in number than required for permanent loading alone. These increases also apply to mechanical fastenings.

Some codes restrict stress and load increases to other values than those given here.

Roof trusses, arches and other roof framing take snow increase while columns almost always are critical under wind combined loading.

The writer knows of no publication which gives loading classification for ships, boats and barges but it would seem reasonable to use snow-combined-stresses for load, flotation, and wave actions and wind-combined or even impact for grounding and collision shock stresses.

Load conditions of glued members are the same as for solid timbers.

Stress Derivation

Working stresses of timber are derived by three separate operations:

(1) Small, clear specimens of unseasoned wood are broken to obtain ultimate breaking strength.

(2) Breaking strength is reduced for a factor of safety to allow for variability within a species, effect of long time loading and of a general safety factor. Such reduced values are termed basic stresses.

(3) Basic stresses are in their turn further reduced for grade defects such as knots. These final values are termed working stresses and used by designers.

Ultimate Breaking Strength

Breaking strengths for commercial American woods are given in the Wood Handbook *(1)* and Strength and Related Properties of Wood *(2)*.

Two classifications are shown and the values for the dry condition (12 percent moisture content) are much higher than those listed for unseasoned wood.

Since glued members may have a moisture content up to 16 percent, their strength is intermediate between these two and only slightly less than the strength of dry members *(12)*.

Published breaking strengths of wood are based on extensive test laboratory programs that include lengthy and complicated analysis.

Breaking strengths as given in tables are usually for unseasoned wood.

Factor of Safety

Factor of safety is a summation of many interlocking variables and conditions of use. The value of this factor is given as four but the popular conception of it is nearer three or less. Factor of safety is the same for glued as for solid sawn timbers.

Basic Stresses

Basic stresses for clear unseasoned woods under long time service at maximum design loads for commercial American Woods are given in *(5)*, Supplement No. 2. Values for normal loading conditions are ten percent higher than for long time loading *(8)*.

The Forest Products Laboratory has just completed an extensive test program on glued laminated structural members for the determination of basic stresses. Agreement has now been reached on all values except those of compression across the grain. It seems reasonable to assign a ten percent increase to glued construction as compared to that for solid-sawn since stress for solid-sawn is based on surface dryness only and glued members are dry throughout.

The following values give Forest Products Laboratory recommendations for agreed-on stress values and also the writer's suggested increase for compression across grain:

TABLE 1.—BASIC STRESSES IN PSI, COAST REGION DOUGLAS FIR

	Solid timbers		Glued laminated timbers	
	Long time loading	Normal loading	Normal loading	Normal loading
Bending	2200	2400	3000	25
Tension with grain	2200	2400	3000	25
Compression across grain	320	350	385	10
Compression with grain	1450	1600	2200	37
Horizontal shear	130	145	165	16
Modulus of elasticity	1, 600, 000	1, 600, 000	1, 800, 000	12

Percentage increases for other grades and other species are the same except for redwood, for which the increase for bending stress is 22 percent.

The Forest Products Laboratory will soon distribute a glued-construction sign manual which will be submitted to the lumber associations and to timber structural engineers for approval and adoption and for determination and assignment of working stresses. Some modification may occur during the adoption processes.

Strength Ratio

Strength ratio of glued member is substantially the same as for solid sawn timbers. Since in the determination of unit working stresses for joists and planks of which laminations are made, some credit was taken for dryness with freedom from checking the percentage increases of unit working stresses in glued members may not finally be as great as the increase in basic stresses would indicate.

Working Stresses

Strength ratio reductions to obtain working stresses from basic stresses are determined by lumber association technicians *(3, 4, 5)*.

Strength ratio determinations were made in 1934 before the wide-spread use of timber connector trusses and glued members and so do not fit modern usage of timbers too well. A complete revision is now being started by the Forest Products Laboratory. Present practice uses solid sawn grades and corresponding working stresses for glued members but takes advantage of certain stress increases for dryness and for better dispersion of defects.

It seems certain that the extensive test program of the Forest Products Laboratory and careful analysis, acceptance and modification operations will result in a better and more realistic picture of design with glued members. The general trend of development can now be seen but exact details cannot be foretold.

The following stress values give what is believed to be the best and latest practice with indications of future trends as they have appeared.

Working stresses for American commercial woods used under normal loading conditions and in solid sawn timber form may be found in *(7)* of National Design Specifications.

Bending

The Uniform Building Code *(8)* allows a bending working stress 20 percent greater in glued members than that is permitted for the same grade and species in sawn solid timbers. Basic stress increase as found by Forest Products Laboratory is 25 percent. It would seem that a value of 20 percent could well be used. The increase is due principally to drying strength increase and in a smaller measure to defects being limited to one lamination in depth.

Tension With Grain

Tension with grain of glued timbers using scarfed joints in laminations is strong in comparison with solid sawn material since gain is made in both dryness and in lumber defect limitation and dispersion. The Uniform Building Code permits 20 percent increase for glued members as compared to solid-sawn members and this figure, in light of Forest Products Laboratory basic stress increases, seems reasonable and should later be substantiated by the trade.

Grade selection has no merit where tension with grain is the principal stress. Where mixed grades are used for other reasons tension stress of lowest grade shall govern.

It is recommended that proper net sections as recommended in Teco Manual and bolted joint literature be used for connector and bolt joints.

Compression Across Grain

Compression across grain stress is used for connection design but not for member design. Working stresses for glued timbers may be taken as ten percent greater than for solid sawn-timbers of same species and grade.

In glued members, where construction warrants, high compression stress species can be placed where needed.

Values in publications are for bearings 6 inches or more in length. For shorter bearings unit stress may be increased.

Compression With Grain

Since in glued timbers gain is made for dryness and for limitations of defects to one lamination in depth and to dispersion of defects, glued timbers are stronger than solid sawn-timbers in this stress type. Both National Design Specification and Uniform Building Code permit a 40 percent increase for compression with grain. This higher value may well be used.

There is no merit in grade selection for glued timbers stressed principally in compression with grain. Where selection is used then the stress value of lowest grade shall govern. Note the National Design Specification allowance for increase where timbers bear on steel plates.

Horizontal Shear

Forest Products Laboratory tests have shown that basic stresses of glued timbers are about 16 percent higher than for sawn solid and it seems reasonable to believe this increase or more will be carried over into working stresses.

It is well known that the checks and splits which occur in sawn solid timbers and weaken horizontal shear strength do not occur in glued timbers.

It is recommended that 16 percent higher shear values be used in glued timbers.

Note that the National Design Specification permits 50 percent higher shear stresses in joint details than for member design *(7)*.

Modulus of Elasticity (E)

Dry lumber is stiffer than unseasoned lumber and the modulus of elasticity of glued timbers is higher than for sawn solid timbers which may be unseasoned *(1, 2)*.

The Forest Products Laboratory has agreed upon a modulus of elasticity of 1,800,000 p.s.i. for glued Douglas fir and southern yellow pine, which is a 12.5 percent increase over the 1,600,000 p.s.i. permitted for sawn solid timbers. The same percentage increase may be allowed for glued members of other species.

Few realize fully the true relationship of E to various grades, or to various conditions of loading, service, or zone selection.

Since E does not vary for strength ratio it is unnecessary to use the higher grades where stiffness is critical. Often where for certain grades design finds deflection critical a lower grade may well be used and the same size member retained.

Use of percentage increases for temporary loading operates to make deflection more often critical while use of percentage decreases for

service conditions operate to make deflection less often critical.

If stiffness is critical for permanent loads in a particular member then temporary load increase for other stresses is of no value.

Stiffness is most often critical for long spans and light load combinations.

A higher E can be used for glued members than for solid.

Tension Across Grain

Tension across grain is a minor type of stress used in joint design but not in member design. The Uniform Building Code permits a stress value which equals one seventh of that allowed for compression across grain and such values may be used.

Combined Bending and Compression

Combined bending and compression strength of glued timbers shall be determined by the standard formula used for such purpose in solid sawn-members.

Miscellaneous Stress Types

Such stress types as hardness, vertical shear, cleavage, crushing and other like qualities of wood are not structurally critical in either glued or solid sawn timbers.

Design Formulas

Glued laminated members shall be designed by the same engineering formulas that are used for solid sawn wood members except as hereinafter mentioned.

When all end joints in a member are required to be scarfed and when scarfs are properly made, effectively glued, and properly dispersed, the member may be considered as structurally effective for its full net cross section.

Where laminations have end butt joints, or stepped or dovetailed joints, such joints shall not be considered as transferring stress and laminations shall not be considered as structurally effective for a distance equal to twelve times lamination thickness on each side of centerline of joint.

Glued members may be bored and routed as is done in solid sawn timbers and load values of fastenings in glued members are the same as used for seasoned solid sawn members.

Curved Members

For the curved portion of a glued member, the allowable unit working stress in bending shall be modified by multiplication by the following curvature factor:

$$1 - 2{,}000\left(\frac{t}{R}\right)^2$$

where $t =$ lamination thickness in inches
$R =$ radius of curvature in inches
t/R shall not exceed $1/100$

No curvature factor shall be applied to stress in the straight portion of a member regardless of curvature elsewhere.

In members curved to a radius less than 250 times the thickness of a lamination in that portion of the member, stressed 60 percent or more of allowable working stresses, scarfed joints shall be required.

For portions of a member in which the laminations are curved to a radius of less than 150 times their thickness the slope of grain in those laminations within one-tenth the depth of the assembly from the outer face of each outer lamina shall not be steeper than 1 to 15.

Curved glued beams of moderate curvature properly designed for deflection, shear, and bending moment, will not produce appreciable thrust at supports and may for design purposes be considered as straight beams, and no horizontal thrust at supports considered.

Curved truss chords are continuous members subject to combined axial thrust and bending actions.

Truss action produces axial thrust (T) along top chord which tends to act along a straight line between panel points but which is forced to follow curved shape.

Transfer of thrust from straight line to curved line produces bending moment of thrust times eccentricity or Te. Since the top chord is a constant-section continuous member we may say that positive moment at panel point is Te/2 and negative moment at midpanel is Te/2.

Where roof load by virtue of sheathing or joists produces uniform load on chord then we have a beam action negative moment at panel point and a beam action positive moment at midpanel. Such moments are compensating to eccentric moments produced by curvature. Such compensation remains in the same com-

parison ratio for all variations of live load from zero to maximum since live load variations have like effect on both roof load and eccentric moments.

Bending Actions

Loads on a beam produce bending moments and the beam sets up an equal and opposite resisting moment reaction. Bending moment produces tension on one side and compression on the other. Strength of tension flange acts about strength of compression flange as a couple to form resisting moment. Lever arm of couple is distance between tension and compression flanges.

For convenience a glued beam may be considered as being divided for depth into ten equal zones.

TABLE 2.—ZONE STRENGTH VALUES

Zone (1)	Maximum stress (2)	Average stress (3)	Strength (4)	Lever arm (5)	Moment (6)	Moment percent (7)
1	1.0f	0.90f	0.09fbd	0.9d	$0.081fbd^2$	50.0
2	.8f	.70f	.07fbd	.7d	$.049fbd^2$	30.0
3	.6f	.50f	.05fbd	.5d	$.025fbd^2$	15.0
4	.4f	.30f	.03fbd	.3d	$.009fbd^2$	4.5
5	.2f	.10f	.01fbd	.1d	$.001fbd^2$	.5

(a) Values in maximum stress column (2) are ratios of maximum possible stress either tension or compression in individual zone to maximum allowable working stress. These values are illustrated graphically in Fig. 1a, b. Values in individual zones for various allowable working stresses are given in Table 3.

(b) Values in average stress column (3) are ratios of average stress either tension or compression in individual zone, as compared to maximum allowable working stress.

(c) Values in strength column (4) are total strength of each zone in pounds. Values are product of average stress values column (3) and area bd/10 of each zone. Values may be either tension or compression. Zone strengths illustrated graphically in Fig. 1c.

(d) Values in lever arm column (5) are length of lever arms of individual zones expressed in terms of beam depth. In beam resisting moment action each zone on compression side acts as a couple about equal-in-strength zone on tension side. Values here are taken from center to center of zones which is not quite true but error introduced in small and unimportant. Lever arms are shown graphically in Fig. 1d.

(e) Values in moment column (6) are respective resisting moments of zones and a true measure of work performed by each zone in resisting beam bending moment, and hence in carrying beam loads. Values are products of zone strength column (4) and lever arm column (5) and expressed in inch pounds. Values may be either tension or compression resisting moments. These values are illustrated graphically in Fig. 1d.

(f) Values in moment percent column (7) are percentage of total resisting moment either tension or compression carried by respective zone. Note that outer zone carries 50 percent of the load and that zone 5 which lies adjacent to neutral axis carries only one half of one percent of load. Surely outer laminations are all powerful and central laminations are comparatively weak.

An outer lamination may be likened to a man working long hours and accomplishing much, while an inner lamination may be likened to a boy working short hours and accomplishing little. This situation shows up clearly in tests where outer laminations fail so regularly that test observers are almost inclined to believe that all strength lies in outer face lamination.

TABLE 3.—MAXIMUM WORKING STRESSES FOR VARIOUS ZONES

(1)	Working Unit Stress (2) p.s.i.	Zone One (3) 100 percent	Zone Two (4) 80 percent	Zone Three (5) 60 percent	Zone Four (6) 40 percent	Zone Five (7) 20 percent
(a)	2400	2400	1920	1440	960	480
(b)	1900	1900	1520	1140	760	380
(c)	1450	1400	1160	870	580	290
(d)	1100	1100	880	660	440	220

In Table 3 working unit stress values in column (2) are illustrative working unit stresses in bending. They are values designated by notations f_c and f_t. Percentages and stress values given are maximum that can occur in individual zones without exceeding allowable working unit stresses. Values in zone one are identical to those values in column (2) since here values are 100 percent.

In a glued beam we may vary cross section instead of grades and thus keep bending stress constant. Percentage stress variation values given in Table 3 may also be used as area variations for constant stress in all zones. Constant stress cross sections with material at center of beam and with material at sides of beam are illustrated in Figs. 1e, f.

As we consider the length of a beam we find that maximum zone stresses as explained really occur at only certain critical points of maximum moments in the center for length, and then reduce to zero at supports or inflection points.

In continuous beams the stress in laminations change from compression to tension and from tension to compression as we go along beam and change sign of moment. Other areas may be low or zero stress sections. Change of stress for length as well as for cross section zones may be taken into account in allocating material, scarfs, or defects. Bending stresses are applied in design of glued members as for solid timbers.

Stress variations for zones as given herein apply only to bending action. All laminations and entire member must also be suitable to resist shear and deflection actions.

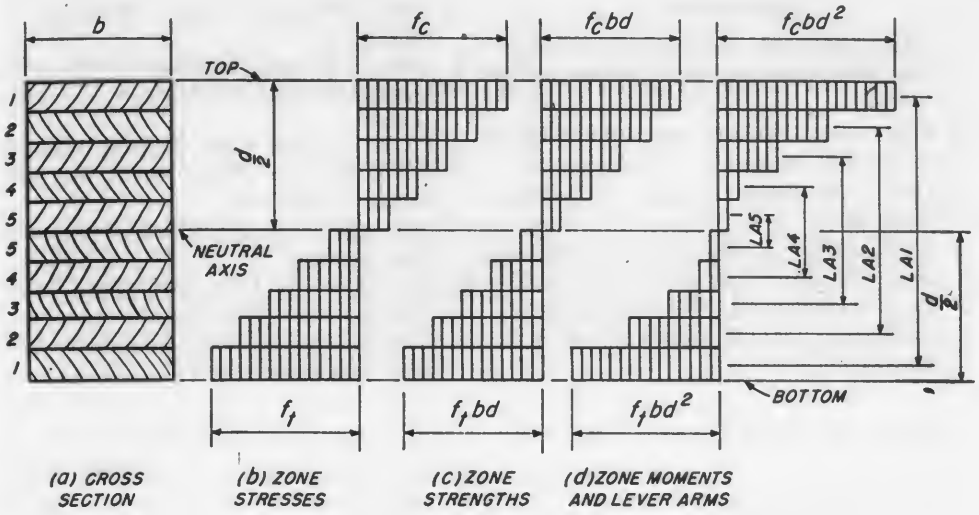
Space does not permit descriptions of lumber, glues, nor laminating processes in this article. Excellent material on these items may be found in (9) through (21) of the references cited. Comparative sizes of glued and solid timbers to comparative working stresses are given in Table 4.

Literature

1. Wood Handbook, 1940 SOD.
2. Strength and Related Properties of Wood, FPL.
3. Guide to the Grading of Structural Timbers and the Determination of Working Stresses — Miscellaneous Publication No. 185, February 1934, FPL.
4. Supplement to Miscellaneous Publication No. 185—May 1940, Corrected 1943, Bulletin No. R1225—FPL.
5. Supplement No. 2 to Miscellaneous Publication No. 185—June, 1948, Bulletin No. R1715—FPL.
6. Grading and Dressing Rules of Lumber. SPA–NHLA–NLMA–WCLA–WPA and others.
7. National Design Specification. 1944 Revised, 1948. FPL.
8. Behavior of Wood Under Continued Loading—1947—FPL.
9. Laminating of Structural Timber Products by Gluing. Revised 1948—FPL.
10. Glued Laminated Wooden Arch—FPL—1939.
11. The Gluing of Wood, Bulletin No. 1500—FPL.
12. Tests of Glued Laminated Wood Beams and Columns and Development of Principles of Design, Bulletin No. R1687, 1947—FPL.
13. Engineering Laminates—1949—JWS.
14. Timber Engineers Handbook—1948—JWS.
15. Modern Timber Design—1948—JWS.
16. Southern Pine Manual, 1948—SPA.
17. Modern Timber Engineering, 1949—SPA.
18. Uniform Building Code, 1949—PCBOC.
19. Building Code—1949—NBFU.
20. Structural Live Loads, 1948—TSI.
21. Glued Laminated Specifications, 1949—TSI.

TABLE 4.—COMPARATIVE SIZES OF GLUED AND SOLID TIMBERS TO RECOMMENDED WORKING STRESSES

Member	Load Value	Solid Size Inches	Glued Timber Size Inches
30 foot beam	800 lb. per lin. ft.	10 by 20	7 by 19½
16 foot column	167, 000 lb.	11½ by 11½	
16 foot column	215, 000 lb.		11 by 11¼
Compression truss chord	300 kips	3–6 by 16	2–5¼ by 14½
Tension truss chord	310 kips	0–6 by 12	2–5¼ by 14½



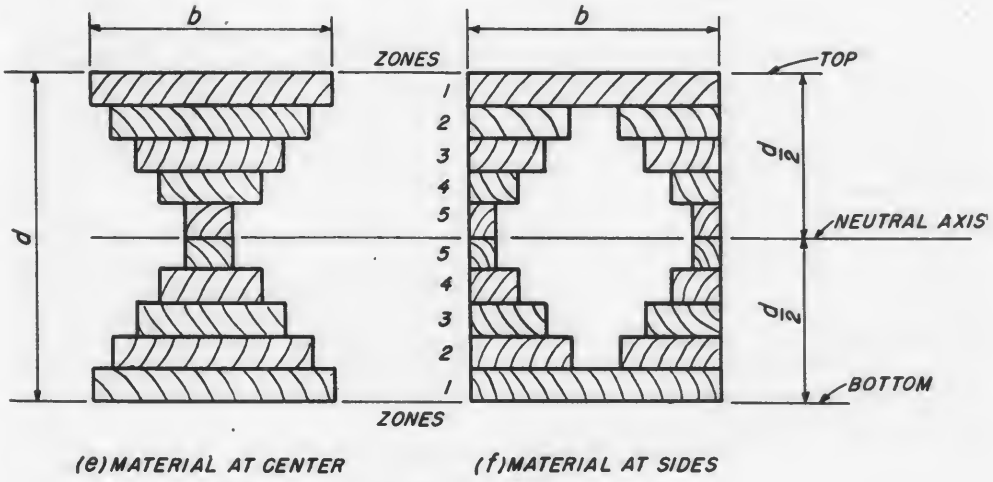


Fig. 1.—Constant stress beam sections.

Key to Fig. 1 Abbreviations

b Breadth of member in inches
c Compression with grain working unit stress in psi
d Depth of member in inches
e Eccentricity of member in inches
f_e Bending Compression WUS in psi
f_t Bending Tension WUS in psi
R Radius of curvature in inches
t Thickness of lamination in inches
T Axial thrust in pounds

Abbreviations

1. *CRA*—California Redwood Association, 405 Montgomery St., San Francisco, California.
2. *FPL*—Forest Products Laboratory, Madison 5, Wisconsin.
3. *JWS*—John Wiley & Sons, Inc., New York, N. Y.
4. *NBFU*—National Board of Fire Underwriters, 85 John Street, New York 7, N. Y.
5. *NLMA*—National Lumber Manufacturers' Association, 1319 Eighteenth St., N. W., Washington, D. C.
6. *NDS* — National Design Specification—NLMA.
7. *NHLA*—National Hardwood Lumber Association, 59 East Van Buren St., Chicago, Illinois.
8. *PCBOC*—Pacific Coast Building Officials Conference, 124 West Fourth St., Los Angeles, California.
9. *SOD*—Superintendent of Documents, Washington, D. C.
10. *SPA*—Southern Pine Association, Canal Building, New Orleans, La.
11. *TSI*—Timber Structures, Inc., P. O. Box 3782, Portland, Oregon.

FOREST PRODUCTS RESEARCH SOCIETY

Glued Laminated Wej-Weld Frames

Axel V. Pedersen

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By using a gusset to join a stud or column to a rafter or beam, a frame can be formed with any desired outline. The gusset is shaped with two or more sloping scarfs in each end, which fit into similar scarfs in one end of the rafter or stud. Whereas ordinary glued laminated construction does not permit a radius of less than 10 feet at the eaves when 1-inch thick (nominal) laminations are used, the Wej-Weld frames permit the radius to be as small as 12 inches when the design is on the principle of a three-hinge arch. All joints are scarfed and glued in this frame so as to develop the full strength of wood into plywood. The gussets are usually made from thick structural plywood, and the studs and rafters from commercially available sizes of lumber. Frames can be made in clear spans up to 60 feet and can be spaced from 2 to 20 feet on centers with height of side walls up to 20 feet. These frames offer a practical solution to the problem of using stock size lumber and plywood. It has been found that these frames can be produced more economically than the standard glued laminated wooden arch.

Historical Background

GLUED laminated wood construction has been in use for more than 40 years in building construction.[1] The technique in producing such material has been greatly improved during the last 10 years, but the difficulty in bending material to a sharp radius makes it uneconomical to use where small radii are desired.

Ordinary glued laminated construction does not permit a radius of less than 10 feet at eaves when 1-inch nominal thick laminations are used. It is desirable in most buildings to have walls vertical, roof line sloping, and with as much clear headroom inside of building as possible.

The Wej-Weld frames described in this paper permit the radius to be as little as 12 inches at eaves when the design is on principle of a three-hinge arch, and, if they are designed as rigid frames, it is up to the designer's ability to develop a finished product having sharp corners or the shape set by architectural requirements.

There has been developed a frame made from thin layers of plywood with butt joints in the individual layers; but this type depends for its competitive cost on waste materials and it will not have the same stiffness as is possible with Wej-Weld frames where all joints are scarfed and glued so as to develop the full strength of wood into plywood.

General Description of Wej-Weld Frames

As shown on Fig. 1-a and 1-b, the gusset is used in joining the stud or column to rafter or beam and thus forming the frame, giving the desired outline of the frame. It may slope one way only, as shown on Fig. 1-a, or slope from eave to peak (Fig. 1-b). Gussets are generally made from thick plywood[2] or they may be formed from bending and gluing very thin laminae to give the desired shape.

Studs and rafters are shaped from commercially available sizes of lumber. They may be of different species of wood, receive different treatment, and dimensions may be different. Finish of stud may be rough and the rafter finished, and either may be of different shape.

The gusset is shaped, as shown on Fig. 1, with two or more sloping scarfs in each end and they fit into similar scarfs in one end of the rafter or stud. When this joint is set with glue, the stresses from loads will transfer from one individual piece to the other.

Plywood made from ⅛-inch thick laminations in thicknesses varying from ¾ inch to 2⅝ inches are the dimensions generally available.

Thickness of lumber is generally 1, 2, or 3 inches, seasoned to the proper moisture content. Frames have been made in clear spans up to 60 feet and can be spaced from 2 to 20 feet on centers with height of side walls up to 20 feet.

[1] Wilson, T. R. C. *The Glued Laminated Wooden Arch.* U. S. D. A. Tech. Bull. 691 (1939).

[2] Douglas Fir Plywood Association. *Technical Data on Plywood.* Tacoma, Washington.

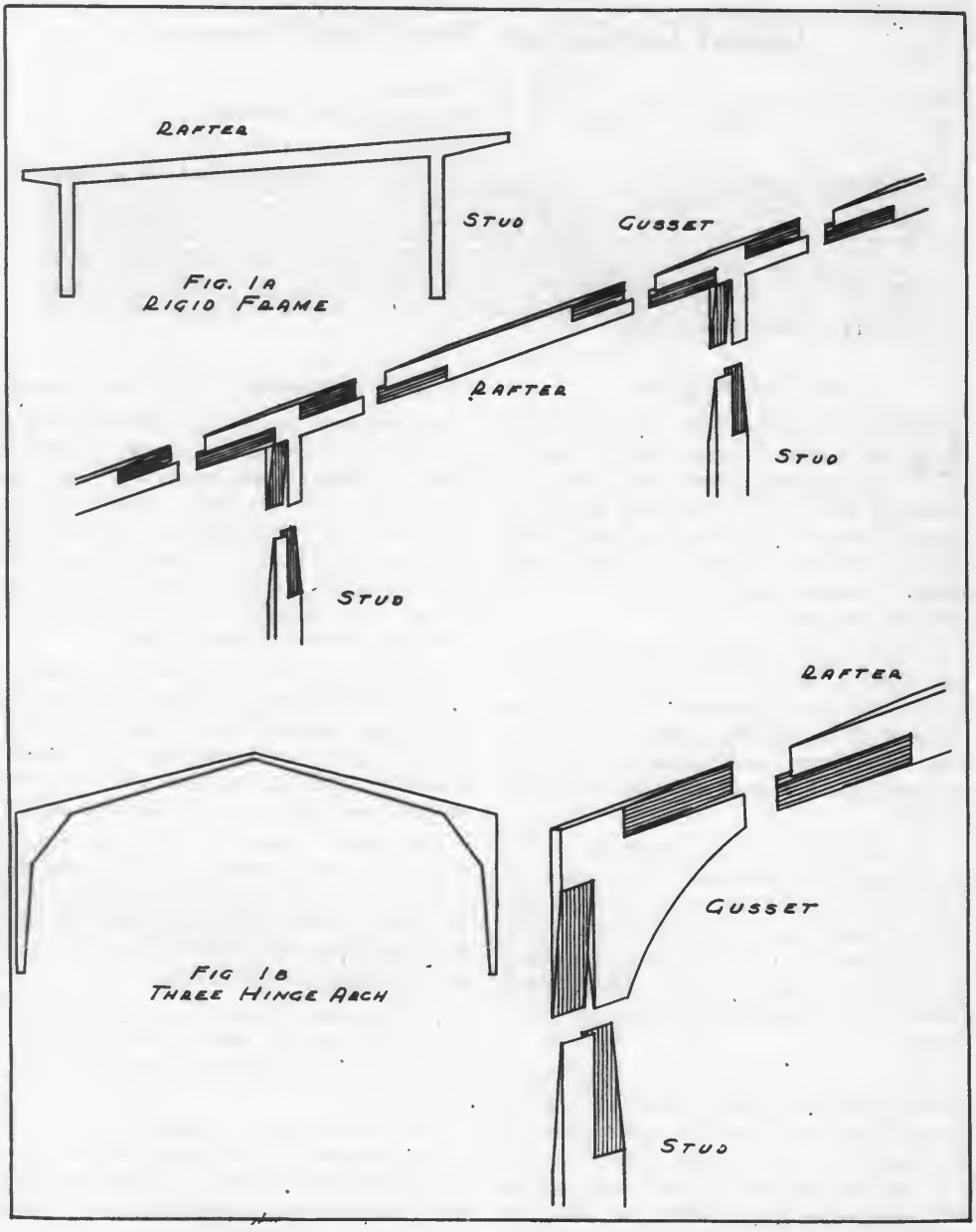


FIG. 1A
RIGID FRAME

FIG 1B
THREE HINGE ARCH

Manufacturing Methods

In order to obtain the best results, lumber must be finish planed on a cabinet-type planer to the exact thickness of the plywood.

The general procedure in gluing must follow the Manual prepared by the Forest Products Laboratory.[3] Scarfs for both plywood and lumber are made on a DeWalt saw with chain feed in order to obtain the required finish on scarfed surfaces. This operation is shown in Fig. 2.

Fig. 2.—Scarfing operation with DeWalt saw.

In widths of materials less than 10 inches nominal size, it is sufficient to have only two opposing scarfs but with wider material it is found desirable to have either three or more in order to minimize the cupping at the scarf joint.

The actual gluing operation may be performed near the site of installation as the total required pressure of gluing the scarfed pieces to develop glue joints of sufficient strength very seldom exceeds 15 tons. A scarfed piece of plywood and the method of clamping is shown in Fig. 3.

Engineering Design and Testing of Frames

In order to ascertain whether design of frames could be made on principles of design found satisfactory for other materials, a test program was undertaken. Two test arches were placed 4 feet on centers, and they were loaded, as shown on Fig. 4 in successive loadings starting with the dead load of 5 pounds per sq. ft. and up to a total loading of 115 pounds per sq. ft.

Fig. 3.—Gusset plate scarfed for assembly and assembly press in background.

Fig. 5 shows the outline of arch shape and the deflections at various points. When loads were removed after 24 hours full loading, there was one hundred percent recovery and it was found that accepted engineering principles would govern design.

Present and Possible Uses for Wej-Weld Arch Frames

During the past 2 years many of these frames have been installed in buildings in California. Fig. 6 shows the interior of a school building of 24-foot span. The building is of prefabricated type with 11 foot height at eaves and with a 1:12 slope of roof. Arches are spaced on 4-foot centers.

Fig. 7 shows a church building located in Los Angeles, California. Arches are spaced on 8-foot centers and the roof is of 2-inch thick sheathing, sloping 8:12. Spans of arches are 31 feet.

Fig. 8 shows an installation of the open-shed type. This planing mill has a 40-foot span with a 5-foot overhang on each side. The frames are spaced on 20-foot centers. Total coverage of the roof is 2,500 square feet.

[3] Knauss, A. C. and Selbo, M. L. *Laminating of Structural Wood Products by Gluing.* Forest Products Laboratory Report No. D 1635 (1948).

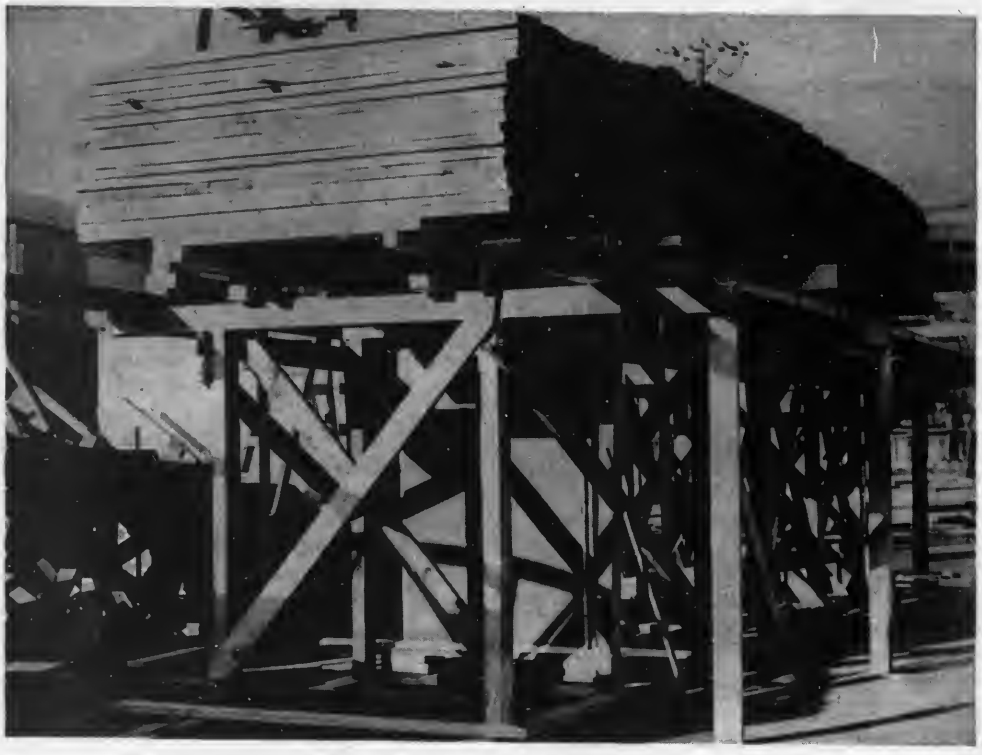
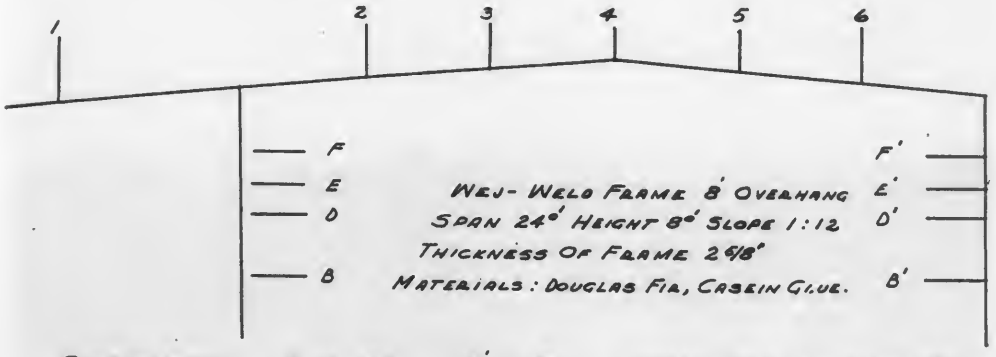


Fig. 4.—End view of arches load tested.



SIDEMOVEMENT IN 32 SECONDS OF AN INCH	F: 2-30	F': 1-8	LOADS APPLIED VARIED FROM 5 LBS. PER. SQ. FT. (DEAD LOAD) TO 115 LBS. PER. SQ. FT.
	E: 2-26	E': 1-4	
	D: 2-24	D': 1-2	
	B: 2-16	B': 1-0	

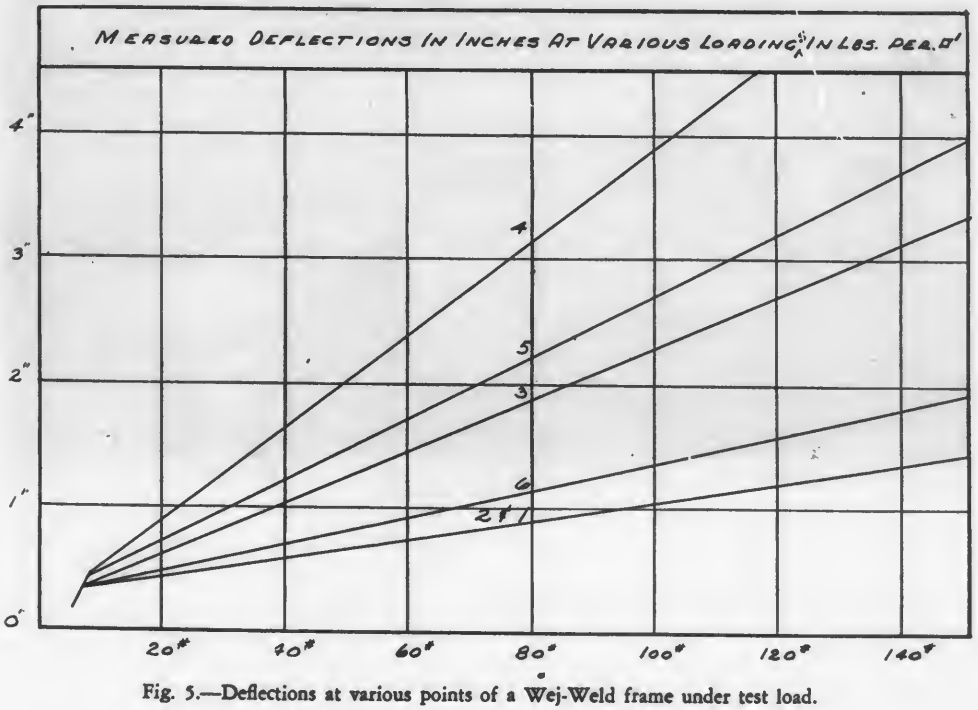


Fig. 5.—Deflections at various points of a Wej-Weld frame under test load.

Fig. 6.—School classroom.

Fig. 7.—Church in Los Angeles, California.

Fig. 8.—Planing mill showing overhang.

Numerous installations have been made for general utility buildings for industrial and farming purposes, using various types of wall and roof covering, such as wood, aluminum, steel, and prefabricated panels, or any conventional type, including plastered walls. The rigid frame is being accepted in house construction, especially modern types of design where open ceiling and large window openings are desired.

Conclusions

The Wej-Weld frames are a practical solution to the problem of using stock size lumber and plywood, as suggested in Item 5 of Additional Research Needed, from Construction Design Problems, as outlined in Forest Products Research Guide.[4] Due to the application of the scarfing method, rolling shear is of very little importance, and it is possible to employ standard engineering principles in design.

Furthermore, with a positive glue joint and all materials following the same modulus of elasticity, stiffness in various parts of the frames can be determined.

The design can be made so it becomes easy to assemble the various parts at the site of erection with the use of nails, or any other simple method of pressure producing fasteners. In practice it has been found that these frames can be produced more economically than the standard glued laminated wooden arch.

[4] American Forest Products Industries. *Forest Products Research Guide in Fundamental and Applied Research.* Washington, D. C.

Discussion

E. George Stern (Virginia Polytechnic Institute): The Wej-Weld frame is a development of immediate appeal to the designing engineer. In order to design Wej-Weld frames as rigid frames, however, the stiffness factors for the frame joints have to be known. Since in the scarfed joint the fiber directions of the overlapping frame member and plywood gusset vary with the veneer layer of the plywood gusset and since the strength of the frame member may not be fully developed by the plywood gusset, it is necessary to know the actual fixity factors of the gusset-plate joint in order to determine the efficiency of the rigid frame on the basis of scarfed joints between timber and gusset.

Thus, it is desirable that the fixity factors for the basic scarfed joints between timber member and plywood gusset be established and made available to the designing engineer and architect. When such data will be available, the Wej-Weld frame should be widely used by designing engineers and architects because of its simplicity in both design and construction.

Mr. Pedersen: The modulus of elasticity for Douglas Fir and Douglas Fir plywood is the same according to the Wood Handbook, and the stiffness of the frame the same at all points.

I believe that it has not been called to your attention, that the method of joining the wood to the plywood is superior to the straight scarf. The joint, due to its self aligning ability, will be strong enough to carry the usual dead load of the structure without any fastener. Glue will fix the joint in the desired position and unite all pieces to act as a frame. Failure occurs generally in rolling shear in plywood near the joint, with no, or only slight, separation at the edges of the joint.

D. E. Kennedy (Canadian Forest Products Laboratory): I would like to point out that the proof loading placed on Mr. Pedersen's Wej-Weld frames was left in place for only 24 hours. Compared with the test made on the arch in Ottawa this test might be less severe even though the proof load was 115 p.s.f. compared with 94 p.s.f. because of the long-term loading effect. The 94-pound load was left on the Ottawa arch for about 6 months.

Mr. Pedersen is to be congratulated on his development of an arch which can carry stress around corners without the necessity of making sharp bends in the lamination. It is definitely desirable to avoid the bending of wood wherever possible.

The only possible objections to Mr. Pedersen's design are purely theoretical in nature. All of the load is carried through two scarf joints only and the failure of one of these might result in complete collapse of the structure. This contrasts with conventional glued laminated construction in which the failure of one scarf joint would seldom reduce the strength of the member to a dangerous value. However, experience and testing are always superior to straight theory, and if Wej-Weld frames prove their worth in service, they will undoubtedly fill a need for attractive, economical roof supports for many types of buildings.

Mr. Pedersen: There is no doubt that the test made at Ottawa was more severe than our test; but we were mainly concerned about proving our method of design in relation to deflection.

It appears that I have overlooked to point out the novel method to join the wood to the plywood. The nature of the multiple scarf is such that it is able to sustain the ordinary dead load without any fastener or glue. The joint is easy to inspect at all times, and as we are not subjecting the scarf to bending stresses, as is the case with curved laminations, we can depend on the joint.

M. B. Wells (Aetna Plywood and Veneer Company): The scarfed glued joints in these frames are required to resist bending moments that are practically in the plane of the joints. Under such conditions the maximum shearing stresses occur on the areas farthest from the center of gravity of the area of the joint. When the amount is excessive, failure may be expected to start on these outer areas and progress toward the center until the whole joint has failed. The wood being joined is stressed in tension or compression parallel with the fibers, in shear parallel with the fibers, in rolling shear perpendicular to the fibers, and in combinations of these stresses in intermediate areas. There are not enough published experimental

data on these problems to permit an exact analysis.

Similar problems arise in designing wood trusses made up of members joined by glued plywood gussets at the joints. Nails are often used to give the necessary pressure on the glue. Loads deflect these trusses causing secondary stresses, bending in the members and shearing moments in the glued joints, in addition to the direct stresses. Such construction is being used on small trusses. No failures have come to our attention.

Mr. Pedersen: It is very true that there are not enough published data available about plywood properties.

The statements made are correct; but the development of the scarf joint is what makes it possible for us to make the frames.

Our tests have proven this type of joint to be superior to the simple scarf joint. Tests of recent date with loadings up to 85 p.s.i. gave failure in plywood in rolling shear; but the joint itself was better than 90 percent intact.

The joint we employ is very simple to assemble. It locks itself and it is possible to inspect such joints at all times.

Our testing program has been carried over a period of the past five years, and we have found it difficult at times to procure properly manufactured plywood.

Radio Frequency Heating as Applied to Furniture Manufacture

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and
Paul D. Newhouse
Consulting and Application Engineer, Northwestern District Engineering & Service
Westinghouse Electric Corporation, Chicago, Illinois

THE need for specialization in the furniture industry is emphasized by the competitive market now developing. The furniture manufacturer is called upon to produce better products cheaper and faster. New production tools, methods, and machines play an essential part in any modernization program because of the continued high cost of labor and raw wood stock. Radio frequency generators have proven to be a useful production tool for cost reduction in increasing numbers of gluing operations in the furniture industry. The purpose of this paper is to assist the furniture manufacturer to decide whether a particular gluing operation is economically justified or physically adaptable for RF heating.

If the gluing operation in question is one that can be handled by a standard RF wood-gluing press, the press maker will furnish a cost proposal so that the economics can be studied. Standard presses are now built for flat stock gluing using 10-kw. size generators. Most assembly gluing operations are not adaptable to standard presses. Many high production assembly items justify the application of smaller RF generators, such as the 2- to 5-kw. sizes. Cost information on suitable electrodes, holding jigs, and pressure clamps can be obtained from either the press or RF generator manufacturers. The information needed to analyze a wood gluing problem effectively has been discussed elsewhere.[1]

Assembly gluing is a relatively new field for RF heating. Fabrication of the many different products in the furniture industry requires that special electrode arrangements be provided for the various types of glue joints. An experimental investigation was made in the laboratory to determine the maximum gluing rates with typical basic glue joints. Two general electrode shapes were used as shown in Fig. 1. A typical arrangement for one test is also shown in Fig. 1.

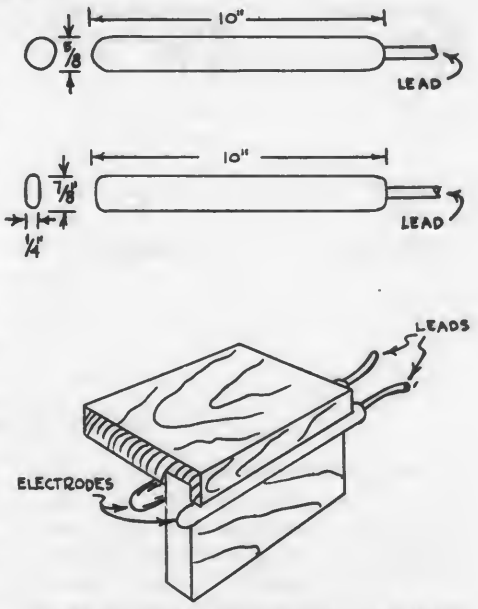

Fig. 1.—Typical electrode construction and arrangement.

The test specimens were of ¾-inch oak and maple stock, 5 inches wide. All joints were cut on edge grain. A typical reinforced urea resin glue was used in all tests. The RF generator was a 10 kw–15 MC unit operated at a low

[1] *Information Required to Analyze RF Wood Gluing Applications*, Woodworking Digest. April, 1948, p. 67.

power level. The electrodes were parallel tuned with a 7-turn coil of ¼-inch copper tubing, 4 inches long and 1½ inch in diameter. An RF voltmeter indicated the electrode voltage. The circuit was adjusted for the maximum RF voltage that could be maintained without arcing. The minimum heat-time cycle was determined for approximately 90 percent glue set as determined by the wood tear after breaking the sample.

of the joint. An example is in the assembly gluing of wooden luggage cases where the top and bottom are glued to the ends and sides in a single operation. In this case the inside is not accessible for electrode insertion. The optimum electrode arrangements found when both electrodes must be external are shown in Fig. 3.

The optimum heating times and electrode voltages determined for the different joints during the tests are listed in Table 1. The

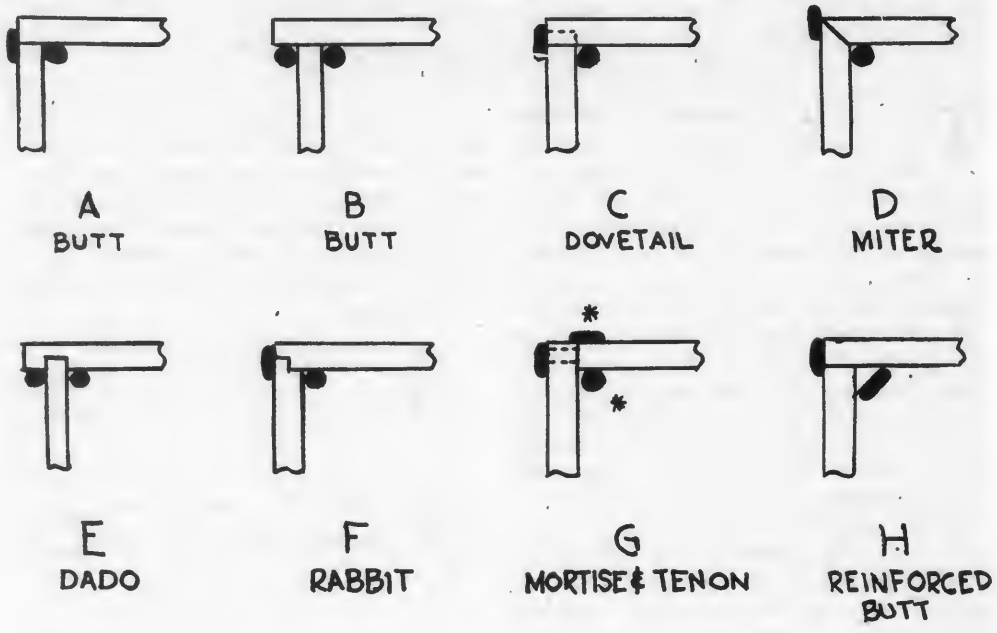

Fig. 2.—Best electrode arrangements for various joints.

A study of the effect of frequency indicated that 15 MC was about optimum, as 5 MC requires higher voltage to glue the joints in equivalent time and increases the tendency to arc. Thirty MC frequency delivers a larger proportion of the RF power into heating the wood adjacent to the electrodes and is therefore wasteful.

The best electrode arrangement for each type of joint tested is shown in Fig. 2. In each case an attempt was made to provide a high concentration of power in the glue line. Often it is not practical to place an electrode on each side

power level used in these tests was low for the 10-kw generator and therefore great accuracy was not obtained. The actual production values ranged from 60 to 130 square inches of glue line per kw-minute. An average value of 100 square inches of glue line per kw-minute can be used for rough estimates of power required in typical assembly gluing applications. A few observations and conclusions were made during the tests.

(1) The electrode voltages should not exceed those shown in Table 1.

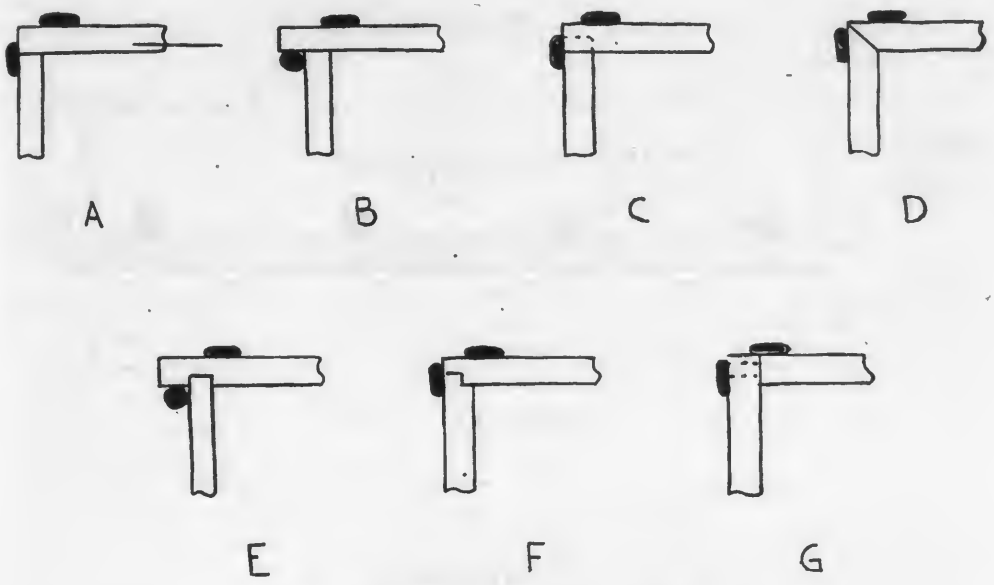

Fig. 3.—Best arrangements for external electrodes.

(2) The excess glue that squeezes out should be wiped off before the application of RF power if possible.
(3) The electrodes should be placed in direct contact with the glue line or be located as close as practical.
(4) The glue should be spread uniformly over the joint.
(5) The electrodes should be isolated from other metal parts to prevent field distortion and power loss.
(6) Kiln dried varnished maple wood has proved to be a convenient practical insulating material for electrodes and fixtures.

A few tests were made in the laboratory to determine the effectiveness of stray field gluing of veneer to core stock. The simple electrode structure shown in Fig. 4 was used to obtain a measurement of the effectiveness of RF stray field heating for use in gluing veneer to soft

TABLE 1.—GLUE JOINT INVESTIGATION

10 kw—15 MC RF Generator at Low Output

Samples: ¾-inch oak, 5-inch wide edge grain joints
Power: Plate voltage 2500 volts plate current, 0.15 amps freq. = 15.5 MC
Glue: Urea resin
Production: (60 to 130) avg. 100 square inches per kw-minute

Type of Joint	Electrode Arrangement Refer to Fig.	Minimum Heat Cycle Seconds	Optimum RF Electrode Voltage Volts
Butt	2-A	12	2500
Butt	2-B	15	2500
Dovetail	2-C	15	2500
Miter	2-D	15	2500
Dado	2-E	15	2500
Rabbit	2-F	15	2500
Mortise and Tenon	2-G	18	2500
Reinforced Butt	2-H	20	3000
Butt	3-A	17	3000
Butt	3-B	17	3000
Dovetail	3-C	17	3000
Miter	3-D	20	3500
Dado	3-E	17	3000
Rabbit	3-F	17	3000
Mortise and Tenon	3-G	20	3000

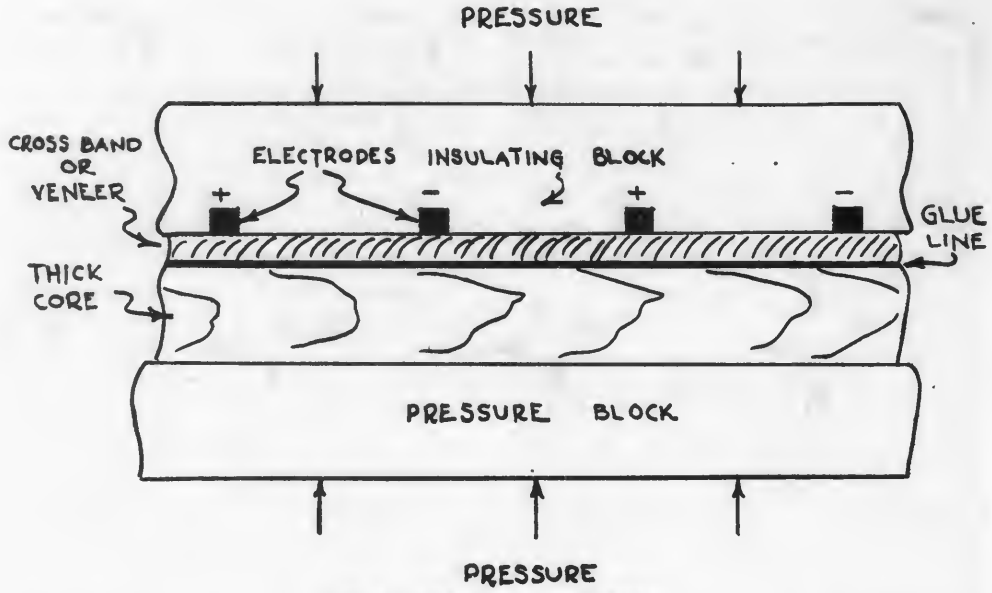

Fig. 4.—Stray field gluing of veneers.

wood cores. It was found that with this arrangement 1/20-inch thick veneer could be glued at the rate of 300 to 400 square inches per kw-minute. A sheet of ¼-inch thick cross banding alone was glued to the core at the rate of 200–250 square inches per kw-minute. When gluing both the cross banding and veneer in one operation to the core a rate of about 200 square inches per kw-minute was found. The veneer glue line set up was 100 percent while about 75 percent of the cross band to core glue line was set. This was considered to be satisfactory for the application. It appears probable that there are a large number of "good" applications in assembly gluing of veneer to core in the furniture industry.

The economics of the application should be carefully investigated before purchase of RF gluing equipment.

The initial and operating costs[2] of RF generators in dielectric heating applications are shown in Table 2. The initial investment includes an average cost of the generator, transmission lines, simple presses or clamps, electrodes and shielding. The operating cost includes representative 1948 costs of electric power, tube replacement, and maintenance. The duty cycle is the fraction of the time the generator is actually in operation during a working day. In practically all successful applications in the wood industry labor savings, lower unit production costs, higher production rates, savings in floor and storage space, higher quality product, and lower retooling costs during design changes have been realized after the installation of RF gluing equipment. On the other side of the picture, provision must be made for new wood gluing techniques, including jigs, fixtures and electrodes, RF shielding for safety of operator and prevention of unwanted radiation,[3] regular servicing and maintenance of the RF generator are required in successful applications.

The way RF gluing can be applied to speed production in furniture manufacture is illustrated in a recent application. A manufacturer of radio and television cabinets was faced with high retooling costs for every style change which occurred on an average every 45 days. One of the most expensive items involved in a style change was rebuilding of 24 wedge clamps which were used to glue panel frame assemblies. The annual retooling costs were

[2] "Dielectric Heat, Wood-Fabrication Tool", Westinghouse Engineer, Vol. 8, Sept. 1948, p. 143.

[3] This paper is written without reference to patents.

TABLE 2.—INITIAL INVESTMENT AND OPERATING COST OF DIELECTRIC HEATING INSTALLATIONS

Generator Rating KW—NEMA	Initial[1] Investment Dollars	Operating Cost—Dollars per Hour[2] Duty Cycle			
		100%	75%	50%	25%
2	2500– 4000	0.124	0.107	0.094	0.079
5	4500– 7000	.19	.17	.14	.12
10	8000–18000	.40	.35	.29	.24
20	16000–35000	.69	.59	.49	.39
50	40000–70000	1.36	1.13	.90	.67
100	----------	2.98	2.51	2.05	1.59

[1]Total includes generator, transmission lines, presses or clamps electrodes and shielding.
[2]Assumes representative 1948 costs of power, tube replacement and maintenance.

$2,000 yearly for these clamps alone. The production rate was 26 frames per man hour. By changing to RF gluing using a 2 kw–15 MC generator and two home made press fixtures, the production increased to 60 frames per man hour. The initial cost of the RF equipment was $2,500. The annual retooling costs will be about $300. The required floor space was halved. The production bottle neck was removed. Use of urea resin glues reduced the cost of subsequent sanding.

RF heating has proved itself by the large number of varied and successful installations now in production use, in the woodworking industry and also in many other major industries as well. Progressive furniture and woodworking manufacturers cannot afford to overlook the many advantages inherent in this new production tool.

Discussion

E. R. Bell (Forest Products Laboratory): Mr. Berkey has outlined the important considerations that determine whether a gluing operation using radio frequency heating is practical. Such considerations merit careful examination. Wooden electrode supports have been mentioned. Wood is also desirable as an inexpensive, easily fabricated material for frames and presses in radio frequency heating.

Ned Bailey (Woodworking Digest): I know we are all grateful to Mr. Berkey and Mr. Newhouse and their Company, the Westinghouse Electric Corporation, for their presentation on this vitally interesting subject. The fact that the use of RF heating in the woodworking field is comparatively new makes it all the more timely. It is fortunate for us that there are companies sufficiently interested to have their engineers do this development work for us.

I am wondering if we all got the significance of the fact that some of their successful tests were made with oak, which I have been told by some wood product manufacturers, is not adaptable to RF gluing. Also that kiln dried, varnished maple makes a good insulating material.

Other points that I believe will bear emphasis, include the fact that press makers will furnish cost proposals and that your Company will be glad to assist any manufacturer who is interested in getting information on RF heating as it applies to his business.

In your paper, you spoke of a most important material (although you didn't refer to it as such) used in fabricating wood products, you referred to it as glue. Diplomatically you spoke of "a typical reinforced urea resin glue" being used in all tests. To clarify this definition, I wonder would you describe for us exactly what you did use? I am told that the adhesive used, often spells the success or failure of a gluing job, and even more so where RF heat is used. And as the electrode arrangements you have described presumably are for volume production applications, the adhesive becomes even more important. I happen to know of one large furniture manufacturer who still puts animal glue at the top of the list for most of their gluing jobs, whereas their biggest competitor doesn't use it. I mention this simply to bring out the difference in opinion in regard to adhesives. I'm sure the adhesive manufacturers here won't mind if you have to mention a trade name.

M. E. Dunlap (Forest Products Laboratory): (In reply to a question from the floor.) Maple and birch can be readily glued by radio frequency. They must be well surfaced and used soon after machining. It is important that the moisture content of the material be uniform

to assure even heating and proper setting of the glue line.

A. H. Bishop (The New York State College of Forestry, Syracuse University): Messrs. Berkey and Newhouse have done a swell job in the preparation of their paper and I extend my sincere congratulations to them both.

Those of you that were at the Chicago national meeting will agree that considerable progress has been made within the past year into the mysteries of RF gluing. In the days gone by, users of RF equipment and resin adhesives were obliged to rely on their own initiative, but today we find resin manufacturers experimenting with RF equipment and RF manufacturers experimenting with synthetic resins. With that spirit of cooperation, the use of RF gluing is bound to progress.

On page 337, paragraph 3 of your paper you refer to "A typical reinforced urea resin". Is there any such thing as a typical resin? What do you consider the RF conductivity should be for a typical urea resin to be used with high frequency?

On page 338, paragraph 1 of your paper you state that "Minimum heating cycle was determined for approximately 90 percent glue set as determined by wood tear." What is the correlation between wood failure and the percentage of wood cure? It is my opinion that the degree of polymerization does not indicate the strength of the glue bond unless the same resin and its formulation is unchanged.

On page 338, paragraph 3 I believe the words "for this particular resin glue as" should be inserted after the word "voltages".

On page 339, item (2) you say that "The excess glue which squeezes out should be wiped off before application of RF power, if possible." It is often not possible or practical to do so. Of course, it is far better not to let it occur. Excessive squeeze out would indicate too heavy a spread.

On page 340, paragraph 1 you state that "The veneer glue line set up was 100 percent." Does that refer to the area of wood failure or to the degree of polymerization?

On page 340, paragraph 3 you speak of "regular service and maintenance—." What do you recommend as to the period of time between servicing and maintenance and by whom should it be done?

On page 341, paragraph 1 you say that "Use of urea resin glues reduced the cost of subsequent sanding." Why any more so than any other type of glue or method of curing?

RF is not a cure-all. It is not supposed to take dunnage lumber and convert it into a FAS grade. However, the apparatus and synthetic resin adhesive will do a swell job if they are properly used.

In Table 1, the glue is specified as urea resin, and on page 338 you state that it was a typical *reinforced* urea resin glue. The question might be asked if there is any such thing as a typical urea resin. Since there is such a variation in the RF conductivity of different glues, would it not be advisable to express in micro-mhos the actual conductivity of this particular urea resin.

In Table 2 you have determined the operating costs by assuming 1948 costs of power. What cost per KW. was assumed; does the operating cost as expressed in dollars per hour also include depreciation, and if so, on what basis?

Mr. Berkey and *Mr. Newhouse:* When wood is used for supporting electrodes, it is necessary that it be properly dried so that it does not absorb power. It has been our experience that if the wood is first thoroughly kiln dried and then impregnated with a silicone resin while it is still hot, satisfactory practical insulation is obtained.

The adhesive we referred to was a commonly used urea-formaldehyde resin which is advertised as being non-crazin. By "typical" is meant that this glue is commonly used in similar applications. We found the conductivity of a wet sample to be 1020 micro-mhos per CC at a frequency of 10 megacycles.

We had no way of determining the degree of polymerization. When we say that 90 percent glue set was obtained we mean that 90 percent wood failure resulted when the joint was broken open.

Our results are strictly applicable only to the particular glue used. However, similar results are expected with other types of urea resin glues and we prefer not to give the manufac-

turer and number of this glue for fear that it will be interpreted as an indorsement of this particular glue.

Frequently in assembly gluing, the glue is spread by hand; consequently, good control is sometimes difficult to obtain. Any excess glue which accumulates on the electrodes should be removed.

A suggested maintenance schedule is included in the operating instructions with each RF generator. Maintenance essentially consists of cleaning the equipment periodically and usually inspecting for worn parts. The frequency of cleaning is dependent upon the plant operating conditions in which the generator is located. Certain parts, such as dust filters, should be cleaned daily.

Resin glues are more brittle than animal glues and are therefore much easier to clean. The squeeze out can be quickly removed by scraping or sanding. We are informed that the life of a sanding belt is much longer when urea resin glues are used.

The operating costs include the cost of power at 1¢ per KW hour, tube replacement and maintenance. The reader can determine the amortization cost by referring to the column "Initial Investment" and spreading this expense over a period of 5 or 10 years.

In the example we have mentioned in the paper, the customer bought a 2 KW generator for $2260. and built his own fixtures at a cost of less than $500. Over a period of 5 years (10,000 hrs.) the amortization would amount to approximately 28¢ per hour.

We hope to discuss some measurements of the electrical characteristics of wet glues at high frequencies in a later paper.

Basic Stresses For Wood*

J. B. Alexander

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Basic stresses for western Canadian softwood species are given and their application to squared timbers of solid wood, joists, planks, beams, stringers, posts, and timbers is discussed. Average strength properties, as determined by extensive laboratory tests, have been reduced by applying appropriate factors for variability, long-term loading and a factor for safety. By applying a further "grade factor" based on the impairment in strength resulting from the defects permitted in that trade, working or design stresses are secured. Included are a table showing basic fiber stresses for the species covered, illustrations showing the variation in strength of Douglas fir, and data on the relation of basic stress to duration of maximum load.

Introduction

FROM time immemorial man has used wood in some form or another to serve his needs. It was among the first of structural materials used by primitive man in his primitive world, and it remains an indispensable factor in the mechanised world of today. Although its use is older than recorded history, no scientific study was made to determine basic factors which affect the various physical and mechanical properties of wood, and which influence to a marked degree its use for different purposes, until this present century. Trial and error, observation, experience, and judgment, these combined were the principal guides to the selection of species and the dimensions of timbers for use in any particular service.

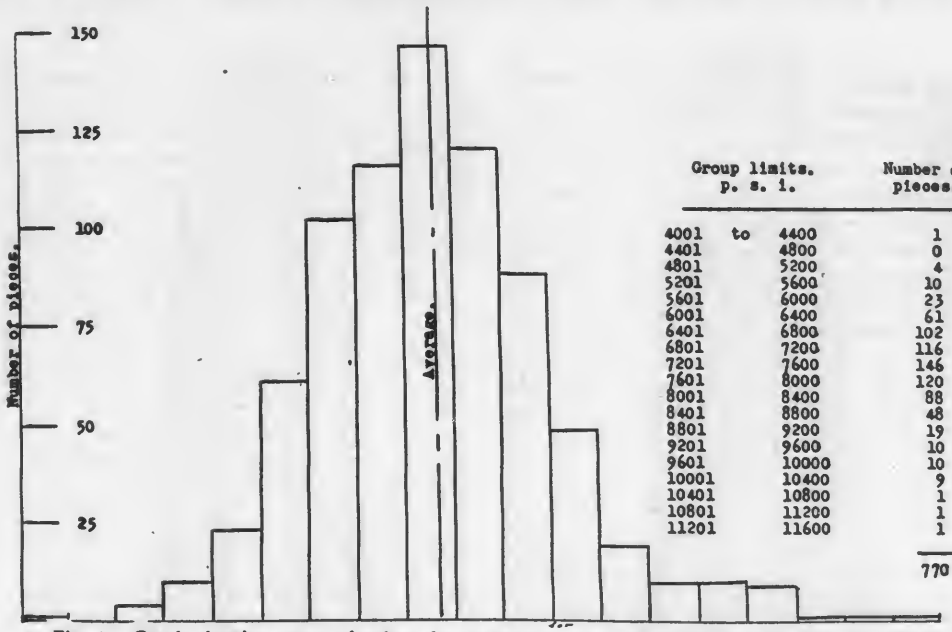
Timber was plentiful and comparatively inexpensive; labor costs were low. If there was any question as to the load-carrying capacity of a given member, one of greater dimensions was prepared and used. However, rule-of-thumb methods of design became outmoded; timbers became more expensive; labor costs rose—all of which added up to a need for more scientific adaptation of the timber available to the particular use. This situation demanded detailed scientific study of the physical and mechanical properties of wood in order to provide dependable data for technical men generally, and for structural designers in particular. As all structural timbers contain some or all the natural characteristics (or defects insofar as structural strength is concerned) which affect the mechanical properties of wood, the basic factors to be determined are the physical and mechanical properties of clear wood, that is, wood which contains no visible defects which might affect these properties. Having made such determinations the investigations can be extended to structural-size timbers in order to assess the effect of the various defects, or combinations of defects, upon the strength of clear wood. Working stresses can then be determined for any given species and any given grade, by using the detailed grade specification and applying proper reduction factors to the strength values for clear wood. Thus it will be recognized that the foundation for all working stresses for any species is the strength value, determined by standard test procedure, of the clear wood of that species.

Basic Stress

Basic stress may be defined as the working stress for clear wood. It is considerably less than the average value for a species which has been determined by laboratory tests, as it must take account of the natural range in strength values from least to greatest for the particular strength function. The lower values of the strength range will exert a preponderating influence, as timbers falling withing this section must be capable of supporting such a load as will produce the working stress and still have a reasonable factor of safety.

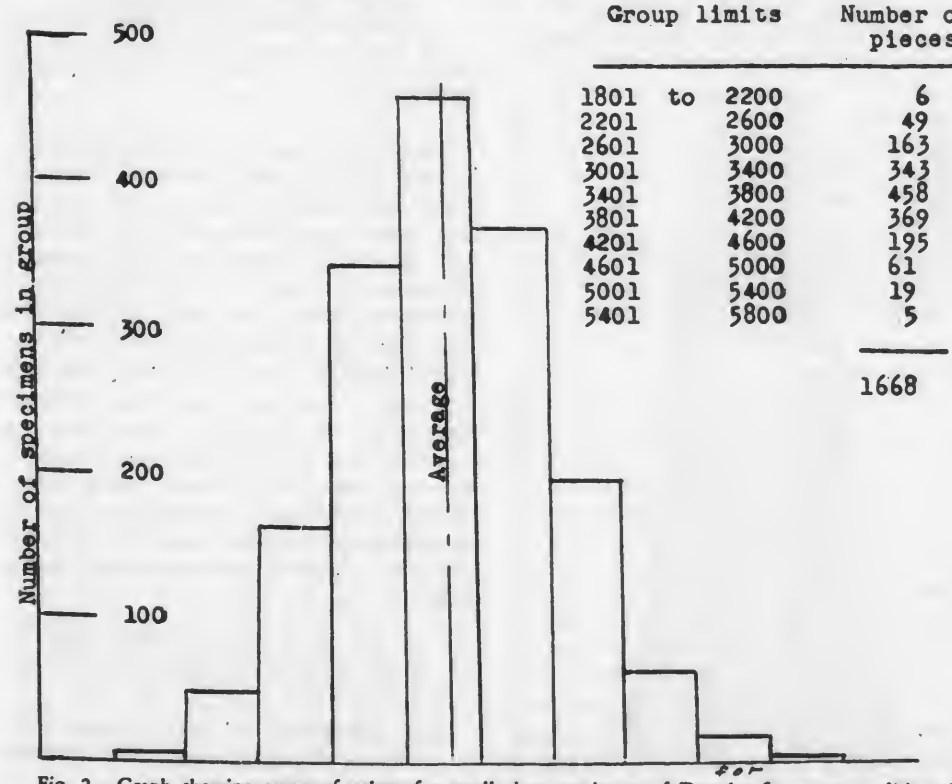
Figs. 1 and 2 illustrate the range in strength values for small clear pieces of Douglas fir in green condition in modulus of rupture, static bending, and in maximum crushing strength, compression parallel to the grain. It may be noted that the high value for modulus of rupture is nearly four times the low and that the high value for maximum crushing strength is three times the low.

* Presented by title only.



Group limits. p. s. i.			Number of pieces.
4001	to	4400	1
4401		4800	0
4801		5200	4
5201		5600	10
5601		6000	23
6001		6400	61
6401		6800	102
6801		7200	116
7201		7600	146
7601		8000	120
8001		8400	88
8401		8800	48
8801		9200	19
9201		9600	10
9601		10000	10
10001		10400	9
10401		10800	1
10801		11200	1
11201		11600	1
			770

Fig. 1.—Graph showing range of values for small clear specimens of Douglas fir, green condition, in modulus of rupture static bending.



Group limits			Number of pieces
1801	to	2200	6
2201		2600	49
2601		3000	163
3001		3400	343
3401		3800	458
3801		4200	369
4201		4600	195
4601		5000	61
5001		5400	19
5401		5800	5
			1668

Fig. 2.—Graph showing range of values for small clear specimens of Douglas fir, green condition, in maximum crushing strength, compression parallel to grain.

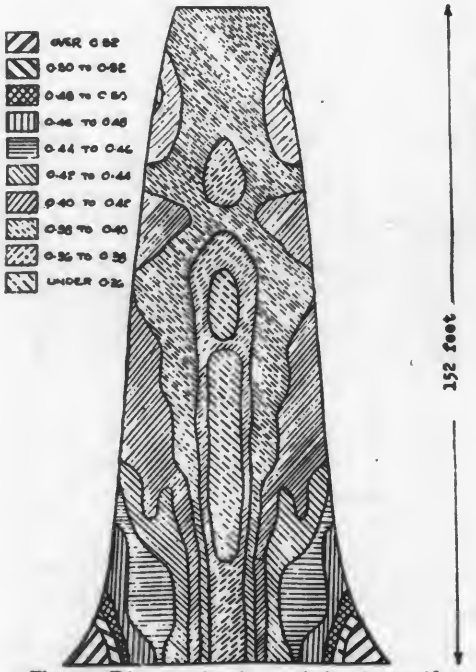


Fig. 3.—Diagram showing variation in specific gravity throughout one tree.

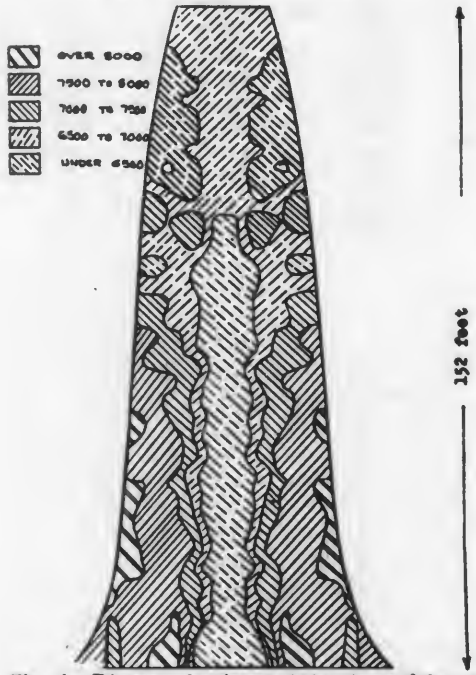


Fig. 4.—Diagram showing variation in modulus of rupture static bending throughout one tree.

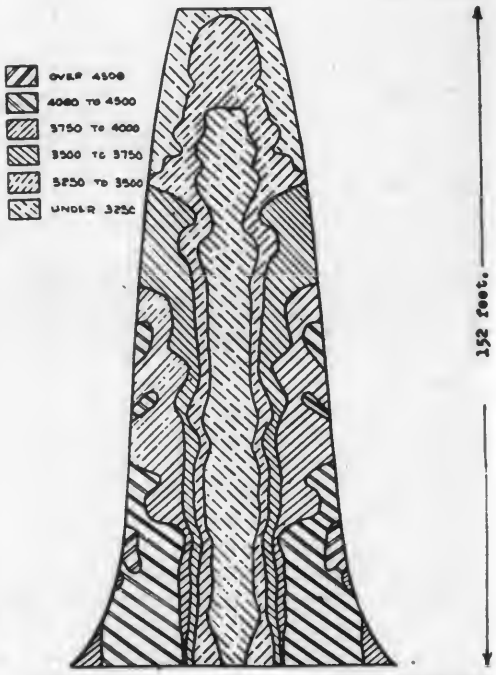


Fig. 5.—Diagram showing variation in maximum crushing strength compression parallel to grain throughout one tree.

All strength functions of wood vary greatly, not only between species but also between different trees of one species and even in material taken from different sections of one tree. Figs. 3, 4 and 5 illustrate the variations found in testing one Douglas fir tree throughout the commercial length of the trunk, 152 feet. The lowest strength values are associated with material adjacent to the pith and in the top logs.

It is to be noted that there are no unknown, undeveloped characteristics of wood which can be drawn upon to increase the average strength values as determined by testing already accomplished. Elimination of a small percentage of material by specifications, carefully worded and competently applied, will result in one of two things:—

1. It will increase the minimum factor of safety without increasing materially the average value.
2. It will permit the use of greater basic stresses without changing the minimum factor of safety.

Mathematical analysis alone is not the only factor which governs basic stresses. Of equal importance are engineering judgment and experience plus a knowledge of the characteristic behavior of a species under test. The matter does not rest there. Similar engineering judgment and experience must be exercised in applying working stresses in structural design for various types of structures and for various conditions of service.

Basic Principals Involved

(a) Competent design
(b) Competent fabrication
(c) Competent grading
(d) Competent supervision of construction and erection
(e) Full consideration of the inherent variability of the strength of wood
(f) Duration of stress at maximum design load
(g) Allowable variations in stress with varying periods of maximum load
(h) A reasonable factor of safety

Limitations in Application

This discussion is applicable to squared timbers of solid wood—joists and planks, beams and stringers, posts and timbers. It does not apply to poles nor to plywood nor, without variation, to laminated construction. Broad general principles are laid down which take account of the inherent general factors common to all species. The basic stresses can be applied with assurance to develop design stresses for structural grades and to cover varying conditions in service by applying proper multiplying factors.

Discussion

The recommended basic stresses are to be used for solid timbers whether green or seasoned, wholly or partially. Thus they are applicable to timbers when fully exposed to climatic conditions. Standard tests of small, clear specimens show marked increases in some strength properties when their moisture content has been reduced to less than that at fiber saturation point, smaller increases in other strength properties, and little increase in still others. In such test pieces the seasoning process can be and is controlled carefully. No seasoning checks are permitted to develop and moisture distribution at the time of test is as nearly uniform as can be attained by perfect seasoning conditions.

Although the wood fibers stiffen and strengthen during seasoning, it has been noted frequently that defects developed during the seasoning period partially or completely nullify this increase in strength. Checks develop and enlarge; shakes open and enlarge; checks develop at edge and corner knots; if cross grain is present serious seasoning checks, which follow the grain, may cause serious injury on that plane. Speaking generally the increase in strength with seasoning is more marked in joists and planks than in timbers of larger dimensions. For this reason provision has been made to give effect to such increase in strength for the higher grades of joists and planks.

In fixing basic stresses, full consideration has been given to the diverse factors and circumstances which, combined, are the criterion for the adequacy of a structural timber to support its designed load. Not all these factors are susceptible to rigid mathematical analysis. Accordingly basic stresses cannot be fixed by this process alone. Test data available determine within close limits the range of strength to be anticipated in clear wood of a species; exceptionally low density, or light weight pieces, can be excluded by specifications but engineering judgment plus experience is the best guide in fixing a factor of safety which is to be applied to specific service conditions.

The basic stresses set forth in Table 1 are premised upon the definite understanding that they are maximum for the service loading. No provision is made for overloads of either short or long duration. Such overloading must result in a decreased factor of safety and if long continued might well cause structural failure. To guard against overloading it is essential to exercise strict supervision during the service life of a structure. For warehouses and similar structures it is highly desirable to post maximum floor loadings on all floors and to make certain that these loads are not exceeded.

No weight should be given to the possibility that a deficiency in strength in a load-bearing timber will be compensated by adjacent timbers having excess load-bearing capacity because

TABLE 1.—BASIC STRESSES FOR WESTERN CANADIAN SPECIES

Species	Extreme fiber in bending or pension parallel to grain	Maximum longitudinal shear	Compression perpendicular to grain	Compression parallel to grain for d = 11 or less	Modulus of elasticity in bending
	p.s.i.	p.s.i.	p.s.i.	p.s.i.	p.s.i.
Cedars					
Western Red	1, 300	120	200	950	1, 000, 000
Yellow	1, 600	130	250	1, 050	1, 200, 000
Douglas Fir (Coast Type)	2, 200	130	320	1, 450	1, 600, 000
Douglas Fir (Mountain Type)	1, 900	110	300	1, 200	1, 400, 000
Douglas Fir, Dense (All Types)	2, 550	150	380	1, 700	1, 600, 000
Fir, Amabilis	1, 300	100	220	1, 050	1, 100, 000
Hemlock, Western	1, 900	110	300	1, 200	1, 400, 000
Larch, Western	2, 200	130	320	1, 450	1, 500, 000
Pine, Lodgepole	1, 300	90	220	950	1, 000, 000
Pine, Ponderosa, Western White	1, 300	120	250	1, 050	1, 000, 000
Spruce, Engelmann, Sitka	1, 600	120	250	1, 050	1, 200, 000

of greater inherent strength and thus having the ability to relieve the low-strength member. Many members in a structure, such as columns and girders, must support adequately their superimposed loads with no possibility of external aid. Basic stresses, therefore, should be formulated on the assumption: "Individual timbers must support adequately their design loads".

For realistic reasons basic stresses are governed by the strength values in the low range of representative material for any species as determined by standard tests. The minimum value obtained is not necessarily the dominant factor. In any normal dispersion (and the sampling for range and quality for wood does approximate normal dispersion closely) a very small percentage of the total number of pieces involved lies near the minimum value. It would be unfair to any species and out of line with good engineering practice to eliminate from consideration all but the minimum strength value, and to base working stresses solely upon that.

Common observation and experience establish the plain fact that no factor of safety, whatever its magnitude, can guarantee absolute freedom from failure in all circumstances.

The factor of safety takes into account and makes proper provision for the natural variability of the material under consideration and assumes competent design, careful and proper fabrication, competent grading, competent inspection, adequate supervision in service, and occasional slight overloads of short duration. No factor of safety can or should attempt to compensate for inadequate design, slipshod fabrication, the substitution of lower grade or ungraded material, incompetent inspection, or abuse in service. It should be borne in mind that timbers are graded as they leave the sawmill and that any subsequent re-manufacture involving ripping or crosscutting will alter the initial grade; also that boring, rabbeting, tenoning, and like operations may so reduce the net section resisting stress or so change the intensity of stress at a critical section as to constitute a grave danger to structural stability.

Long centuries of use and service have established timber in an assured position as an engineering material of primary importance. Rule-of-thumb methods have largely been supplanted by methods based upon sound engineering principles. Basic stresses are premised upon the use of these principles by competent designers who will specify stress-graded timbers, careful fabrication and adequate inspection during erection. Subsequent to erection wood must be protected against deterioration, must have periodic competent inspection, and joints and fastenings must be kept tight in order to insure that every member in a structure is supporting its design load.

Nothing has been said, as yet, concerning adjustments to meet different conditions in service; fundamental principles alone have been discussed.

The responsibility for relating design assumptions to working stresses rests squarely upon the designing engineer. His right to vary stresses to suit varying conditions in accordance with his engineering judgment and experience must be conceded and recognized.

Basic Stresses or Working Stresses for Clear Material, Green Condition

The working stresses shown in Table 1 are intended to apply to clear material of western Canadian species when in green condition. Average strength properties, as determined by

extensive laboratory tests, have been reduced by applying appropriate factors for variability, long-term loading and a factor of safety. By applying a further "grade factor" based on the impairment in strength resulting from the defects permitted in that trade, working or design stresses are secured.

Extreme Fiber Stress, Static Bending

Laboratory testing has determined that the average ratio of proportional limit to ultimate load for short-term loading of small clear test pieces is approximately nine-sixteenths. Although the ultimate load for structural grades is less than for clear timbers, the ratio of proportional limit load to ultimate load is of the order of two-thirds. Although the proportional limit load is not necessarily the limit load for long-term loading, there appears to be close relationship. This factor, combined with careful revaluation and reassessment of test data, and the matured judgment of research engineers in the light of long experience and observation of wood undergoing tests, has been accepted as sufficient justification for an increase of ten percent in old standard basic stresses.

Longitudinal Shear

A large factor of safety has been incorporated in the current design stress when based on laboratory results in shear parallel to the grain. Recognition has been given to the necessity for providing ample safety against highly concentrated stresses and the inevitable checking during seasoning. Further revaluation of data, has led to the conclusion that an increase of ten percent in the basic stress from its current value is entirely justifiable.

Compression Parallel to the Grain

This basic stress as shown refers to short columns only as the unit stress must be reduced with increase in the ratio of length to least dimension until the unit load for a column with an 1/d ratio of 50 has dropped to 15 percent of that for a short column. Previous analyses had indicated a ratio of ¾ for the relation between fiber stress at proportional limit and maximum crushing strength. It is known now, as a result of including new data and further analysis of the results, that this ratio is less than supposed, approximately ⅔. Consequently the basic stress for this function has had already its full complement of stress and no increase is warranted.

Compression Perpendicular to the Grain

Current standard practice in the laboratory is to apply load to radial and tangential faces. There is measurable difference in the load at elastic limit and in the modulus of elasticity, the tangential face showing greater values. Structural timbers rarely exhibit strictly radial or tangential grain on the bearing surface; depending on the section of the log from which they are cut, the growth rings may intersect the faces at any angle between 0° and 90°. This type of wood will reach the limit of proportionality at much lower unit loading than either radial or tangential material and its modulus of elasticity is markedly less. Wood supporting a load in side compression is subjected to continuous compression of the wood fibers, and a limited overload will merely mean slightly greater compression. In these circumstances, a factor of safety approximating one is considered adequate, provided the average value, as determined by laboratory tests, is reduced one-third to allow for variability. No increase in current design stresses is justifiable, unless for material which will see service in dry conditions at all times.

Modulus of Elasticity

This is not a mechanical property but a physical constant which has been determined by computation from records of static bending tests. The value currently standard has been proved adequate through service records and inspections. No change is recommended or warranted for short-term loading. Modification to take into account the continuing deflection (creep or plastic flow) which accompanies loading of long duration will be discussed later in this paper.

Adjustment of Stresses

Structural timbers will not always be used in what may be termed "normal" conditions for want of a better description. Strictly speaking, adjustments should be made on grade-stresses rather than on basic stresses. However, the two are interlinked inseparably so that the subject may be developed logically here.

Duration of Stress

Of prime importance to any designer of timber structures is the length of time during which the individual timbers will be required to support the design loads. The basic stresses shown in Table 1, with the single exception of modulus of elasticity are for use in long-term loading with full loads; long-term loading is taken to mean twenty-five years or more. Few structures will be required to perform this exacting service. A special, invaluable characteristic of wood permits it to support overloads of a large order of magnitude for short periods or to support overloads of smaller amounts for longer periods. Designers can make good use of this feature. Figure 6 shows the relation between basic stress and duration of load (Data, U. S. Forest Products Laboratory).

Factors Which Affect Stress Adjustments

1. Plastic deformation or sag.
2. Moisture reduction (seasoning).
3. Density or specific gravity.
4. Exposure in service.

Plastic Deformation

It is a well-recognized fact that under a long-continuing load wooden beams continue to deflect until, in time, the initial deformation may be doubled. Unless the load is at or near the maximum load little need for apprehension exists. For various reasons it may be necessary to limit the maximum deflection, in which case one of two courses may be followed: (a) the maximum dead load can be doubled; (b) the modulus of elasticity can be halved in design. Usually course (b) is followed in practice. Regardless of the procedure

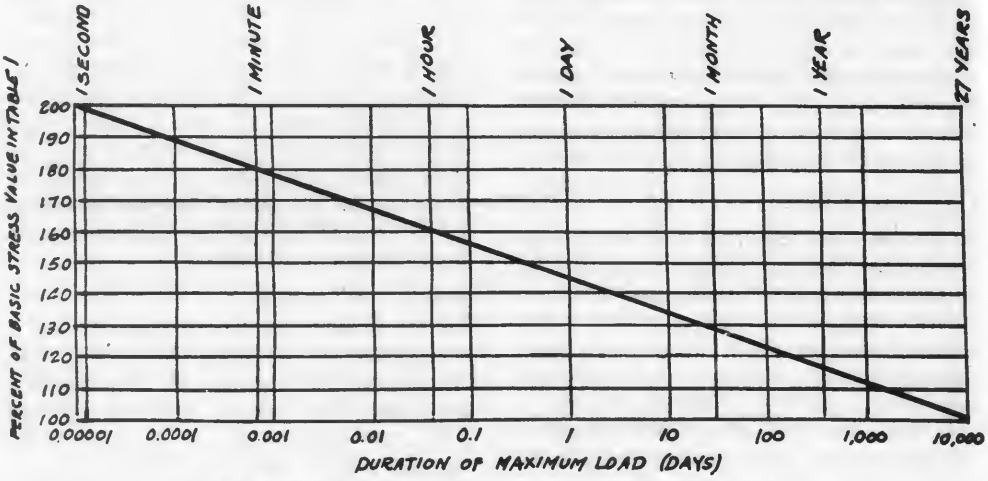


Fig. 6.—Relation of basic stress to duration of maximum load.

It has been determined by long-term loading at the U. S. Forest Products Laboratory that repeated loadings with intervals of rest between produce a cumulative effect but that the sum of all periods of full loading is the equivalent of a single period of continual loading for the same total time. Thus if a structure is to be fully loaded for a cycle of 6-month periods the basis for selecting design stresses is the anticipated sum of the 6-month periods, not the single 6-month period. If repeated loads fail to produce stresses less than design stresses, no account need be taken of them.

adopted it must be understood clearly that deflections will increase continually under long-term loading. Variations in temperature and humidity will affect the rate of deflection and the total deflection.

Studies by the U. S. Forest Products Laboratory have determined that a continuing deflection at a decreasing rate is indicative of adequacy in service. If the deflection continues to increase uniformly during a long period of time a careful watch should be maintained. If the rate of increase suddenly accelerates failure is imminent.

Moisture Reduction (Seasoning)

Although marked increase in wood strength properties of small clear specimens with reduction in moisture below fiber saturation point is a well-established fact, no such increases are to be anticipated for structural timbers. In such material the stiffening and strengthening of the fiber is largely, if not wholly, offset by defects which develop or enlarge during the seasoning process. This is particularly true for timbers of large dimensions and for the lower grades. For joists and planks (material 2 inches to 4 inches in thickness) used in permanently dry situations, bending stresses may be increased safely by approximately 20 percent. A similar increase is justifiable for short columns when built up of material 4 inches or less in thickness but cannot be applied to long columns.

A marked increase in strength perpendicular to the grain has been noted for seasoned material; consequently if maintained in a permanently dry location, a 20 percent increase over green values is recommended.

Density or Specific Gravity

Design stresses one-sixth greater than basic stresses have been in use satisfactorily for a long period for "dense" grades. This factor is confirmed.

Exposure in Service

All basic stresses in Table 1 are premised upon the use of lumber in dry locations, or in continuously submerged conditions, where there is little or no decay hazard. This hazard should be taken care of by preservative treatment, by using the heartwood of species known to be decay-resistant, by proper ventilation and construction, or by some combination of methods developed by experience and proved successful in service.

The object of the study and analysis of all data available has been to determine basic stresses which will be fair to the producer, fair to the designer, and fair to the owners of structures involved. It is believed that structures designed on the foregoing principles, erected by competent workmen after competent training and loaded in accordance with the maximum design loads will comply with that masterly description of ideal design penned, strangely enough, by an eminent lawyer and judge, Oliver Wendell Holmes, in "The Wonderful One-Hoss Shay":—

"It should be built so it couldn't break down
'Fur', said the Deacon, 't's mighty plain
Thut the weakes' place mus' stan' the strain;
'N' the way t' fix it uz I maintain,
Is only jest
T' make that place uz strong uz the rest' ".

Short-Time Creep Tests on Douglas Fir*

Albert G. H. Dietz

Associate Professor of Structural Engineering, Department of Building Engineering & Construction, Massachusetts Institute of Technology, Cambridge, Massachusetts

Exploratory tests are reported in which the creep of carefully matched specimens was measured. These specimens were also matched with static test specimens in direct tension, direct compression, and in bending. The tests were designed to determine in a general way the creep behavior of wood over a range of stresses from low to high. Although no attempt is made to draw any general conclusion, the tests appeared to indicate that in direct compression creep rates are very low below the proportional limit, that they are low in direct tension, and that bending tension and compression creep rates are also low.

Introduction

IN A previous paper,[1] the results of a series of static tension, compression, and bending tests to determine and to correlate the stress-strain relations in carefully matched specimens of Douglas fir were reported. By means of cemented electrical resistance wire gages, it was possible to determine the strain distribution across the depth of a beam in bending and to determine the relationship between the bending stress-strain behavior and the behavior in direct tension and direct compression.

In the series of tests here reported, the same technique was employed to measure the creep of carefully matched specimens; matched also with the static test specimens in direct tension, direct compression, and in bending. These tests were exploratory and were designed to determine in a general way the creep behavior of wood over a range of stresses from low to high. No attempt was made to carry out the tests over a very long period of time and the tests in all instances were completed in approximately 100 to 800 hours. The purpose was to determine more than anything else the range of stresses in which creep might be appreciable and, if possible, the range of stresses in which failure might be expected to occur in a relatively short time. The series was undertaken because it appeared that no similar work had been reported, and, consequently, exploratory studies appeared to be indicated.

Material

The material employed was carefully selected, even-growth, medium-density, straight-grained Douglas fir. The specimens were cut from the same planks as the specimens in the previously reported static tests. Their mechanical properties are summarized in Table 1. Half of the specimens were conditioned to a moisture content of 9 percent and half to a moisture content of 24 percent. Compression specimens, as shown in Fig. 1 were square blocks 3 inches in height, varying in cross section from approximately ½ by ½ inch to approximately 1¼ by 1¼ inches. Tension specimens were as shown in Fig. 1 and consisted of members tapered at the central section to cross sections varying from approximately ⅛ by ½ inch to approximately ¼ by 1 inch. Bending specimens were beams 1¼ inches thick by 5 inches deep and 5 feet 6 inches long.

Specially fabricated resistance wire gages, employing Constantan wire 0.001 inches in diameter, were cemented to the surfaces of the specimens as shown. On the compression and tension specimens, the wires were formed into a hairpin shape, 1½ inches long. On the bending specimens, the wires were stretched out and cemented straight, parallel to the edges as indicated in Fig. 1, which shows the arrangement and distances between adjacent gages. Gages 1 and 15 were cemented to the top and bottom. All gages on all specimens were in pairs arranged on opposite sides or edges of the test specimens so that an average strain representing the axial strain, could be obtained. After the gages had been cemented and the lead wires soldered, all specimens were carefully wrapped in soft paper and then sealed completely in aluminum foil to prevent any loss or gain of moisture from the blocks during the progress of the test.

* Presented by title only.

[1] *Stress-Strain Relations in Timber Beams of Douglas Fir*, Albert G. H. Dietz. A. S. T. M. Bulletin, No. 118, 1942.

TABLE 1.

Direct Stress	Modulus of Elasticity, 10^6 psi. E_c	Modulus of Elasticity, 10^6 psi. E_t	Proportional Limit Stress, psi.	Percentage of Ultimate Strength	Ultimate Strength psi.
Compression:					
Dry	1.98	----	4950	70	7150
Moist	1.78	----	3050	69	4500
Tension:					
Dry	----	2.05	----	--	15000
Moist	----	1.83	----	--	12750

Bending:	Load, lb.	$\frac{Mc}{I}$, psi.	Neutral Axis, Percentage of Depth	Strain in Extreme Fiber, 10^{-3} in. per Inch ϵ_c	ϵ_t
Cycle I	0	----	----	----	----
	800	1500	51.5	0.70	0.78
	1800	3500	52.5	1.53	1.88
	3800	7300	52.5	3.18	3.71
	1800	3500	53.0	1.53	1.88
	800	1500	52.5	0.70	0.78
	0	----	----	----	----
Cycle II	0	----	----	----	----
	1800	3500	51.5	1.49	1.93
	4300	8300	52.0	3.61	4.37
	4700	9000	53.5	4.13	4.93
	4300	8300	53.0	3.99	4.75
	1800	3500	53.0	1.87	2.35
	0	----	63.0	0.14	0.37
Ultimate	4800	9200	54.0	4.19	5.04
Proportional Limit	3850	7400	----	----	----

Loading Procedure

Compression

Groups of three of the compression blocks were centered between ½ inch thick cold-rolled steel plates, placed in a beam-type testing machine, and loaded by means of steel spheres and springs. The load was left on for the desired period of time and increased or decreased according to the loading schedule. The test was inspected daily, and if the load had decreased, it was adjusted to the required value. With the springs employed, it was found that the test load at no time dropped more than 1 or 2 percent per day, and during the latter portions of the test the load usually dropped not at all or only a small fraction of a percent. Twenty-four specimens, half at 9 percent moisture content and half at 24 percent moisture content were tested in this manner.

Tension

Four tension specimens at 9 percent moisture content and four at 24 percent moisture content were tested simultaneously by arranging them in pairs end to end and suspending the four pairs by means of shackles and bolts in such a manner that each specimen was equally and axially loaded. The assemblage was suspended in a testing machine and spring loaded in a manner similar to that employed for the compression specimens. The assemblage was inspected daily and if necessary, the load was adjusted if it had dropped off over night. Here again the drop in load was not more than 1 to 2 percent and usually was considerably less.

Bending

Beams were loaded at the third points by means of calibrated springs, which were placed in tension by threaded rods pulled against bearing plates which in turn compressed the springs. Loads were applied and a daily adjustment made.

Strain Measuring Procedure

Because the resistance wire gages were specially fabricated for this purpose and were not standard strain gages, it was necessary to develop a special strain measuring circuit. This consisted of a modified direct-current Wheatstone bridge in which the strain gage formed one arm and a dummy gage or a ballast the opposite arm. Changes in the resistance of the strain gage were measured on a third arm of the bridge. The sensitivity of the circuit was such that strains of one hundred thousandth inch per inch could be measured with a maximum error of approximately 5 percent. The stability of these gages over long periods of time had previously been checked by placing gages on wooden strips which were bent to

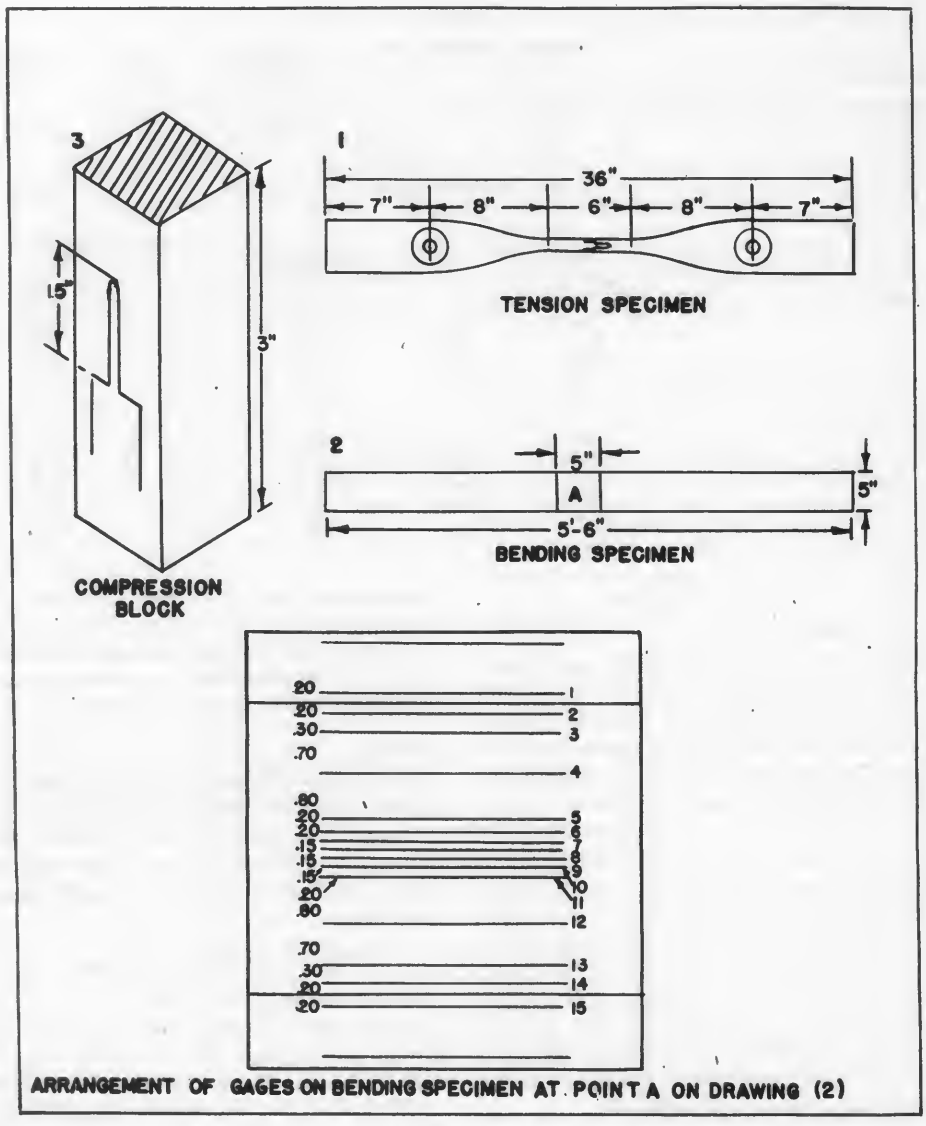


Fig. 1.—Typical compression, tension, and bending specimens.

produce strains of 2 percent in the gages and held for periods of 8 weeks in a constant temperature humidity room. The gages had proven to be completely stable.

Results

Compression

Fig. 2 gives the results of creep tests in direct compression on material at low moisture and at high moisture contents. Only four low moisture and four high moisture specimens are reported because the results on the others were similar. In the upper left-hand portion of the figure is shown the first series of tests carried over a period of approximately 200 hours. Stresses were adjusted upward as indicated on the graph so as to rise on specimen No. 1, for example, from 690 p.s.i. to 5300 p.s.i. The

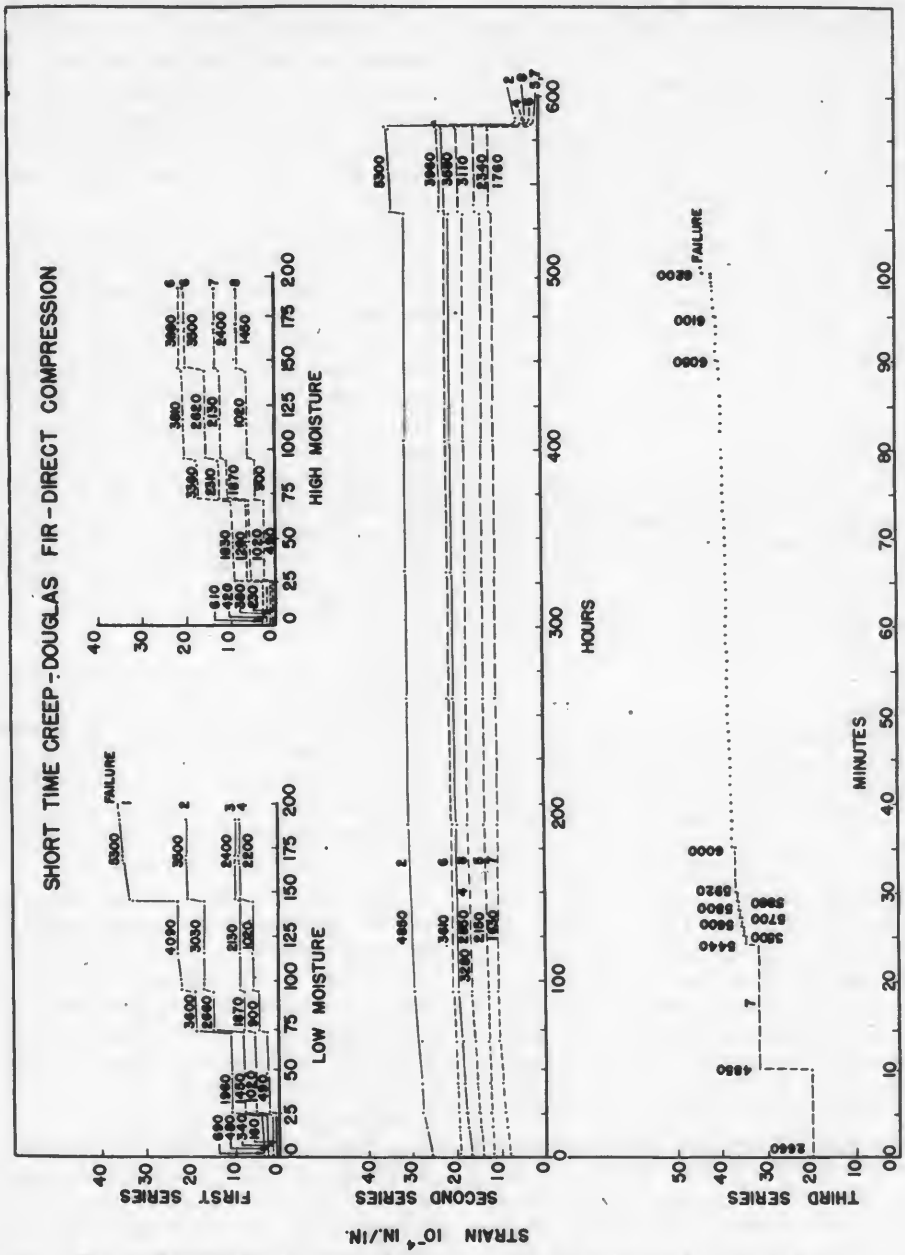


Fig. 2.—Results of creep tests in direct compression on material at low moisture and at high moisture contents.

spread at the lowest stresses, therefore, is from 160 to 690 p.s.i., and at the highest stresses, from 2200 to 5300 p.s.i. Similarly the spread on materials at high moisture contents is from 230 to 610 p.s.i., at the low stresses, and at the highest stresses, from 1450 to 3880 p.s.i.

In this first series, the stresses were adjusted upward at intervals of 25 to 50 hours as indicated. Failure finally occurred at 196 hours in specimen No. 1 at a stress of 5300 p.s.i., or 74 percent of the static strength (Table 1). In the low moisture specimens (specimens 1 to 4) the creep rate was quite low except at the very highest stress of 5300 p.s.i. in specimen No. 1. Reference to Table 1 shows that this was the only stress which exceeded the static proportional limit. On the same specimen, the initial creep rate at 4090 p.s.i. was fairly marked, but it soon dropped off.

In the specimens at high moisture content the creep rate in general was slightly higher than in the low-moisture specimens, especially in the initial stages of each stress step, and in the specimens stressed above the static proportional limit. The difference in creep rate below and above the proportional limit was not marked.

Subsequent to failure of specimen No. 1 two of the remaining low-moisture specimens and all four of the remaining high moisture specimens were reloaded as shown in the second series of Fig. 2. The strain gage of the other low-moisture specimen was too badly damaged to allow its re-use. In this series, the specimens were loaded directly to a predetermined value and held for 530 hours. They were then loaded to a somewhat higher level as shown on the graph and held to 580 hours at which time the load was released to determine the amount of residual strain in the specimens. The residual strain varied between 2 and 6 ten thousandths upon release. Low-moisture specimen No. 2 was stressed (4850 p.s.i.) to just below the static proportional limit for the first 530 hours, and to above (5300 p.s.i.) the static proportional limit for the period 530–580 hours. After an initial fairly rapid creep rate at 4850 p.s.i., the creep rate became very small, but at 5300 p.s.i. it was appreciably greater. The test was discontinued before failure because the residual strain upon load release was wanted. It was 0.0006 inches per inch. High-moisture specimen No. 6, although stressed above the proportional limit, did not exhibit any period of marked creep. This was true of all high-moisture specimens. Because the creep rate in all specimens was low, the graphs for all specimens lie nearly parallel in spite of the differences in stress. The scale of the graph does not show the small divergence which actually existed.

Specimen No. 7 was reloaded individually as shown in the third series and the load carried up as shown. This entire loading cycle was completed in 100 minutes and was carried out to determine what stress would be required to cause failure in a specimen which had already been subjected to a considerable period of stress at fairly high values. The specimen was loaded in steps from 2660 to 6000 p.s.i. in a period of 35 minutes, and was held at that stress until 90 minutes had passed, and then was loaded in three steps to 6050, 6100, and 6200 p.s.i. (87 percent of static ultimate) at which stress it failed in just under one minute.

Tension

Fig. 3 gives the results of creep tests in direct tension. In the first series of tests four specimens at low moisture and four specimens at high moisture contents were loaded in successive steps as shown. Failure finally occurred in specimen No. 4 in a period of 125 hours at a maximum stress of 11,100 p.s.i., or 74 percent of the static ultimate (Table 1).

In the tension series, the creep rate in general was somewhat more marked than in the compression series, but the actual rate was not large except at the highest stresses. Because there appeared to be no proportional limit, strictly speaking, in direct tension static tests, no comparison between creep rates and proportional limits can be drawn.

Subsequent to the completion of the first series, two of the specimens at low moisture and all four at high moisture were reloaded as shown in Fig. 3 on the graph. As in the compression series, the specimens were loaded directly to a predetermined value and held. In this instance, the load was held for 625 hours and then increased in steps until a maximum stress of 7880 p.s.i. was attained in specimen No. 3. The load was then released to determine

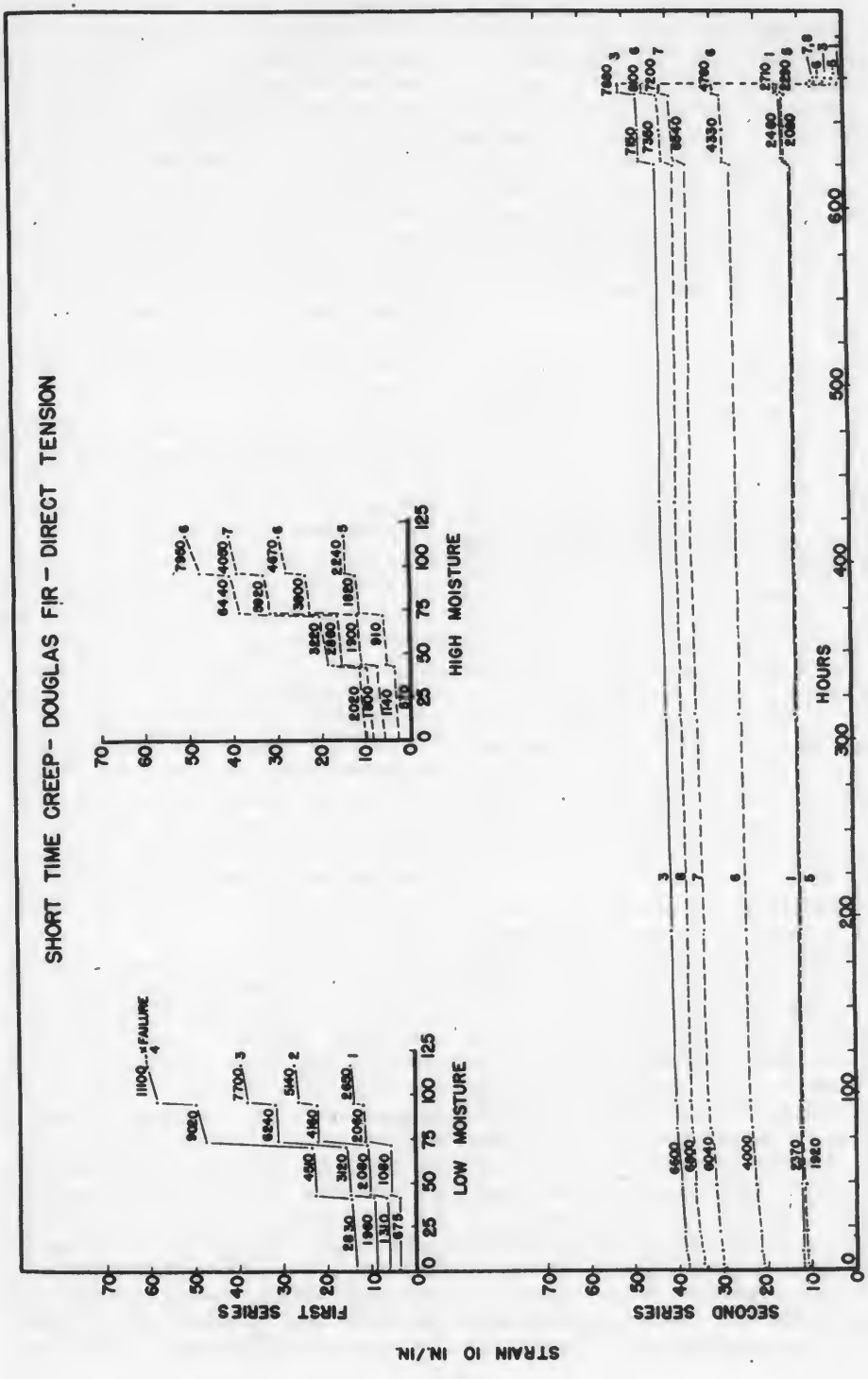


Fig. 3.—Results of creep tests in direct tension.

the amount of residual strain, which was found to vary between 1 and 8 ten thousandths.

Comparison of Figs. 2 and 3 shows that in both the tension and compression tests, the rate of creep in the second series was quite low and became appreciable only when the highest stress was attained. Because the rates were so low, the graphs appear to lie practically parallel at all stresses. Actually, some slight divergence existed; that is, the creep rate at higher stresses was slightly greater than at low stresses.

Bending

The results of one beam test are plotted in Fig. 4. Although two tests were made, the second one was so similar to this one that only one is given here. This beam was loaded over the period of time indicated on the graph, beginning with a relatively low load and increasing at intervals until failure finally occurred. This beam was carefully matched with another beam which had previously been tested under short time loads. If it is assumed that the modulus of rupture of this beam under short time load would have been the same as that of the statically tested beam (Table 1) then the loads applied as shown in Fig. 4 were 35, 63, 70, 79, 82, and 87 percent of the short time ultimate strength, or 40, 72, 81, 90, 93, and 100 percent of the actual ultimate. The computed outermost fiber stresses were 3200, 5700, 6400, 7100, 7300, and 7900 p.s.i. The loading periods were 40, 50, 480, 240, 5, and 20 hours, respectively.

The shape of the strain curves as shown in Fig. 3 is essentially the same as those previously noticed in static tests. The fact that high stresses were maintained for periods of weeks made no essential difference in the shape of the curves. Compressive strains in thousandths inch per inch are plotted to the left of the vertical, and tensile strains to the right. The actual strain distribution deviates from a straight line, as shown. Maximum compressive strains are smaller than maximum tensile strains, and the neutral axis is shifted slightly toward the tension edge of the beam (see also, Table 1).

There was no discernible creep at 35 and 63 percent of the ultimate when loaded for 40 and 50 hours, respectively. When loaded to 70 percent of short time ultimate (approximately the short time proportional limit), creep began to be noticeable and was somewhat larger in compression than in tension, with a slight downward shift of the neutral axis. At 20 days the creep rate had dwindled to practically zero. At 79 percent load creep again occurred, dwindling to an almost indistinguishable rate at the end of 10 days. At 82 percent no creep was discernible after 5 hours. At 87 percent, creep was too small to be plotted but there was a slight diminution in compressive strain at the outermost edge, a slight increase near the neutral axis, small drop in the neutral axis and a slight increase in outermost tensile strains. Failure occurred on the compression side after 20 hours.

Although a number of gages in both tension and compression were damaged during the collapse, enough remained intact to indicate residual strains. The permanent set curve was much the same as for short time loads.

To some degree, the bending creep behavior was a reflection of the compressive and tensile strains. In all three cases, the creep rates were low, except for the very highest stresses in direct compression and, to a lesser extent, in tension, particularly the direct tensile stresses corresponding to the bending tensile stresses. The somewhat greater increase in the bending compressive strains was more or less consistent with the direct compressive and tensile strains.

The bending compressive stresses in the periods 240, 5, and 20 hours were equal to or larger than the ultimate static direct compressive stresses, but the creep rate was low and virtually vanished.

One experimental phenomenon of possible significance was noted. The bending specimens were loaded symmetrically at one-third span; consequently, little or no shear existed in the central portion, but the end thirds of the span were subjected to appreciable shearing stresses, ranging from 1750 to 4400 pounds total, or maximum shearing stress intensities at the neutral axis of 220 to 550 p.s.i. Under these loading conditions, the beams settled continually, and the loading springs had to be adjusted daily, in spite of the fact that the measured creep rate in the central portion of the beam, not subject to shear, was often virtually zero. This would seem to indicate that the continuing deflection of the beam was caused by shear-

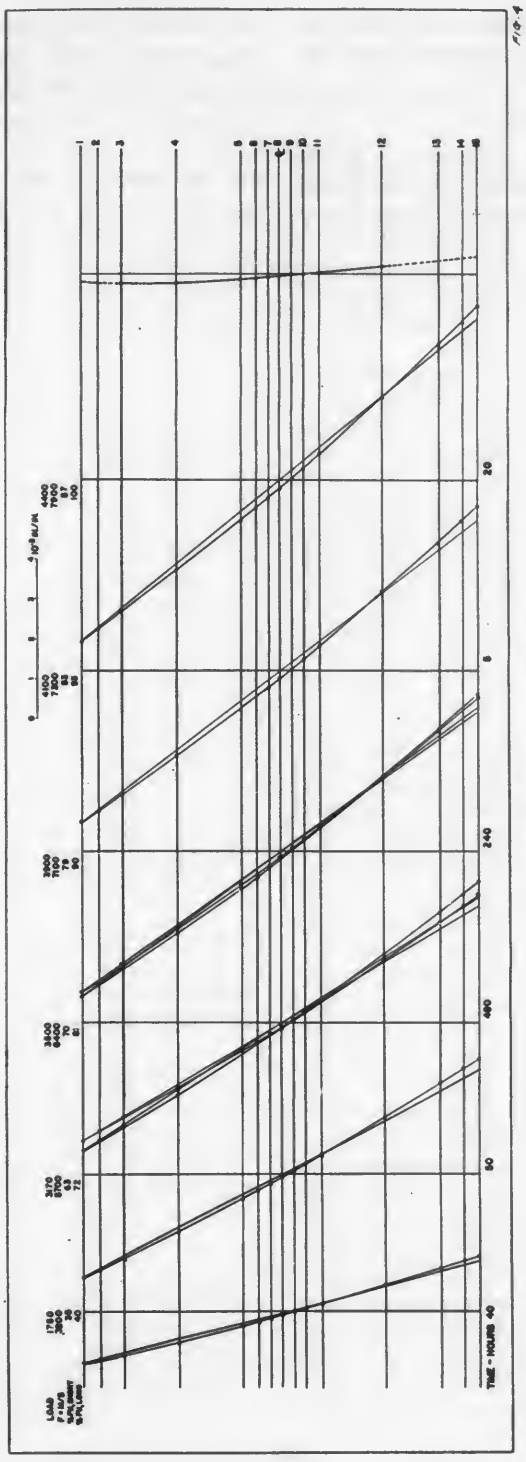


Fig. 4.—Results of beam test.

ing creep in the outer thirds of the beam, because pure bending creep apparently could not account for it.

Conclusions

No attempt is made to draw any general conclusions from these tests. They were purely exploratory and may be useful in setting up more extensive creep studies. They appear to indicate that in direct compression creep rates are very low below the proportional limit, that they are low in direct tension, and that bending tension and compression creep rates are also low. The continuing deflection of beams under load may be caused by shear creep.

Durability of Woodworking Glues for Dwellings*

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The results of the extensive tests made at the Forest Products Laboratory on casein and synthetic resin glues are summarized and the suitability of these glues for use in house construction is evaluated. The results of controlled exposure tests on birch plywood shear specimens and on joints between plywood and framing members, of weathering tests on plywood panels, and of exposure tests on laminated beams made with the glues are shown in tables and graphs. The general superiority in durability of the phenol, melamine and resorcinol glues over casein and urea resin glues under severe exposure conditions is indicated. Casein glues are particularly subject to deterioration under high moisture conditions and the ureas are particularly affected by high temperatures and combinations of high temperature and high humidity exposures.

Introduction

THIS report presents durability data developed by the Forest Products Laboratory on adhesives, that may be used as a guide in the selection of glues for house construction.

Probably one of the oldest examples of glued construction is furniture. During and following the first world war, glue came into use in such structures as laminated arches and airplane parts. In the thirties it became important in house construction; the continuous bond obtainable with glues made possible the stressed-facing type of construction originated by the Forest Products Laboratory for prefabricated houses. It was not until the second world war, however, that glues were developed that combined convenient working characteristics with the high durability needed in severe service.

The glues available in early times produced strong bonds when applied with the proper technique. Because they were low in resistance to moisture, however, they could be used successfully only for service where the glued product was kept dry. Even the development of casein glue, with its improved water resistance which considerably expanded the usefulness of glued products, did not permit prolonged exposures of glued material to high humidity or soaking in water. With the advent of synthetic-resin glues, however, glue bonds as durable as the wood itself became possible even under extreme moisture conditions.

The great expansion in use of glues for structural purposes that has resulted from these developments has created demands for information about their durability. At the Forest Products Laboratory the durability of glues has been studied for many years. The results of these studies have served as bases for recommendations with regard to the types of glues most suitable for fabricating many wood products and structures. As new evidence is obtained, and new and modified glues become available, these recommendations may be revised. In addition, as knowledge of the conditions to which glue joints in wood are exposed in service is expanded, estimates of the effectiveness of various glues can be revised.

Long-term service tests may not always bear out the trends of short-term exposures. In general, however, the longer an exposure test, the more dependable are the conclusions that can be drawn from the results. On the other hand, specimens that were put on exposure 8 to 10 years ago were glued with the adhesives available at that time and more recent formulations may be considerably improved.

Exposure tests are in general very short when compared to the life expectancy of many glued structures. They are, however, generally designed to accelerate possible deterioration or to show the effects of severe conditions that may occasionally occur in service.

The exterior parts of a house are exposed to widely varying temperature and moisture conditions. Data on temperatures that occur in various parts of houses are not available. Maximum temperatures of 215° F. at Tucson,

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* Presented by title only.

[1] This report, prepared in cooperation with the Housing and Home Finance Agency, is based on results obtained in a number of investigations at the Forest Products Laboratory by various workers and done in part with the cooperation of other agencies.

[2] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

Ariz., and 189° F. at Madison, Wisc., however, were registered on the top skin of airplane wings during the summer of 1943 and temperatures above 160° F. were not uncommon during the summer *(3)*. This would indicate that temperatures of 160° F. may develop in exterior panels of houses located in regions of similar climate. Such temperatures are known to damage joints made with certain types of glues. Very low temperatures are encountered in certain localities, but ordinary woodworking glues are usually not affected by exposure to subzero temperatures.

Wood dries to an average moisture content of about 12 percent outdoors in most parts of the United States, but will average as low as 9 percent in the dry southwestern regions and as high as 14 percent or more in regions of high humidity *(9)*. Its moisture content is often much higher for short periods of time, of course, in panels exposed to rain.

Interior woodwork may have a moisture content as low as 4 percent in a heated building in the winter and 13 percent or more in the summer. In the damp southern coastal regions where the houses are seldom heated and both the temperature and relative humidity are comparatively high, average moisture content values of 12 to 13 percent throughout the year have been observed for wood indoors, and for the dry southwestern regions about 7 percent *(9)*.

Besides the average conditions that prevail on exterior panels and on interior woodwork of a house there are certain parts of a dwelling that are often exposed to more severe conditions than others. Woodwork in bathrooms and kitchens is often exposed to condensation and wetting which temporarily may raise the moisture content somewhat above the average values that prevail. While such temporary, abnormal conditions may not have any immediate effect on glues of moderate moisture resistance, the cumulative effect throughout the years may cause such glues to fail.

In houses without basements, the floor panels are often exposed to damp conditions that will result in high moisture content of the wood; this is especially likely to occur where ventilation of the crawl space under a house is inadequate.

Conditions favorable for condensation often occur in walls and attics during the winter in cold climates unless these parts are adequately protected with vapor barriers and attic ventilation. Leaky roofs may also permit temporary wetting of ceiling panels, partitions, and floors. While it may not be economical to build a house of materials that could be soaked or flooded without lasting damage, moderate resistance to extraordinary conditions is desirable.

Glues used for structural parts in housing are often required to retain joint strength under exposure to extremes of relative humidity and temperature. Water resistance may also be required. These various conditions of exposure have been considered in designing durability tests and in selecting glues for long-term exposures.

Animal, starch, flour-extended urea, and the recently developed polyvinyl-resin emulsion glues have been used extensively in the furniture industry, but because of their limited resistance to severe service conditions they are not considered suitable for house construction and are not discussed in this report. The room- and intermediate-temperature-setting phenols of the acid type are not discussed because the data on them are rather limited; available data indicate that they cause deterioration of the wood particularly when the joints are exposed to high temperatures or high humidities *(11)*. Discussion of acid-catalyzed, low-temperature-setting melamines has likewise been omitted, since no extended durability data are available on them and results of preliminary tests indicate that they are not so durable as the intermediate-temperature-setting or hot-press melamines.

Among protein glues, only the casein type is discussed in this report. Glues made from soybean meal are widely used, especially for making interior-type Douglas-fir plywood. When used on this or similar species, their serviceability in well-made joints resembles, in general, that of joints in birch plywood well made with casein glue. Consequently, performance of casein glue in different tests may serve as a guide for use of soybean-glued plywood. Adhesives for which detailed discussion is presented include casein glue, room-temperature-setting, hot-press, and fortified hot-press urea resin, resorcinol resin, hot-press and interme-

diate-temperature-setting melamine resin, intermediate-temperature-setting phenol resin (alkaline type), and hot-press phenol resin.

Glues used in commercial plywood may be of different types depending upon the standards the plywood is made to conform to. Commercial standards have been established by the National Bureau of Standards for hardwood and softwood (Douglas-fir and Western hemlock) plywood. Douglas-fir plywood, under Commercial Standard CS45–47, is of two types, interior and exterior. Interior plywood is generally made with soybean glue or soybean to which a certain amount of casein or blood albumin has been added to improve the water resistance of the glue. Highly extended phenol-resin glues are also used to make moisture-resistant plywood. Exterior-type plywood is generally made with hot-press phenol-resin glue.

Western hemlock plywood as defined by Commercial Standard CS122–45 is made only in the interior type.

Hardwood plywood as established by Commercial Standard CS35–47 is made in four types. Type I requires fully waterproof bond and is usually made with hot-press phenol or fortified urea-resin glue. Type II requires a bond with high water resistance and is usually made with urea-resin glue. In type III only low water resistance is required and may be made with soybean, casein, or extended urea-resin glue. Type IV requires no test for water resistance and is usually made with starch glue.

Test Method and Results

In general, the following four methods of measuring the durability of glued joints have been employed at the Forest Products Laboratory and the results presented in this report are obtained from them:

1. Exposures of small plywood specimens under controlled conditions.
2. Exposures of joints between plywood and framing members under controlled conditions.
3. Weathering tests on plywood panels.
4. Exposure tests on laminated beams.

Exposures of Small Plywood Specimens Under Controlled Conditions

Tests based on exposure of plywood to controlled temperature and moisture conditions have been used extensively to determine the durability of glues (1 and 2). Some of these tests covered a period of 8 years or more.

Test Procedure

Standard plywood shear specimens were prepared from $\frac{1}{16}$-inch yellow birch veneer and glued at 12 percent moisture content. Manufacturers' recommendations for use of the glues were followed. Specimens were tested both wet and dry after a 1-week conditioning period, to determine the original joint quality. Remaining specimens were subjected to the different exposure conditions. At regular intervals, samples were tested for plywood shear strength. Specimens were generally tested in tension-shear in the conditions at which they were removed. Specimens subjected to cyclic exposures were usually tested after the drying period of the cycle.

Exposure Conditions

By exposing specimens made with each glue to well-selected sets of conditions, individual factors that cause deterioration of glued joints can be segregated. The properties of glued joints determined in this way include resistance to high and low temperatures, molds and other micro-organisms, and soaking in water, as well as ability to withstand swelling and shrinking stresses induced in cross-ply construction. Based on their performance under these controlled conditions, glues can be rated with regard to their effectiveness under known service conditions.

Exposure conditions used, and a statement of the significance of each, follow:

Continuous exposure at 80° F. and 65 percent relative humidity.—The effect of aging of the glued joint under mild conditions is measured. In a constant temperature and humidity exposure of this type, the mechanical stresses on the joints would be expected to be lower than under the mildest service conditions.

Continuous exposure at 158° F. and 20 percent relative humidity.—The effect of high temperature at low moisture content is indicated.

Continuous exposure at 158° F. and 60 percent relative humidity.—In this test the combined effect of high temperature and moderate moisture content is indicated.

Room-temperature—high-temperature cycle.—This cycle, consisting of repeated alternate exposures for 16 hours at 80° F. and 65 percent relative humidity and 8 hours at 158° F. and 20 percent relative humidity, measures the combined effect of high temperature and mild swelling and shrinking stresses.

Room-temperature — low-temperature cycle.—This repeated cycle of alternate exposures for 16 hours at 80° F. and 65 percent relative humidity and 8 hours of —20° F. measures the resistance of glued joints to extremely low temperatures. Early results obtained in this test were based upon a low temperature of —67° F. over dry ice.

High and low relative humidity cycle.—In this test, a period of 2 weeks at 80° F. and 97 percent relative humidity alternates with a 2-week period at 80° F. and 30 percent relative humidity in a repeating cycle. Resistance to shrinking and swelling stresses, to molds and other micro-organisms, and ability to withstand the effects of moisture content approaching fiber saturation are measured.

Continuous exposure to 97 percent relative humidity and 80° F.—In this test, resistance to a combination of mold and other micro-organisms and ability to withstand the effects of moisture content approaching fiber saturation are measured.

Soaking-drying cycle.—This test consists of repeated cycles of alternate soaking in water at room temperature for 2 days and drying at 80° F. and 30 percent relative humidity for 12 days. Resistance to shrinking and swelling stresses, to water, and possibly to biological deterioration is measured.

Results of Controlled Exposures On Eight Types of Glues

The results of exposure to these conditions for various periods of time on the shear strength of yellow birch plywood specimens glued with eight types of glue are shown in Figs. 1 to 8. Shear test results for casein glue (without preservative), room-temperature-setting urea resin conforming to Army–Navy Aeronautical Specification AN–G–8,[3] hot-press urea resin, fortified hot-press urea resin, resorcinol resin, hot-press melamine resin, intermediate-temperature-setting phenol resin (alkaline type), and hot-press phenol resin are plotted separately.

Fortified urea resins generally contain a certain amount of melamine resin or resorcinol. Since the type of fortifier is usually not disclosed, results with resorcinol- and melamine-fortified ureas are combined under fortified urea resins. The results with the two types have not as a rule differed significantly, although the melamine-fortified glues have appeared to be slightly superior in durability to those fortified with resorcinol. Again, durability probably would vary with the amount of fortifier used.

The curves shown in each graph represent average joint strength after exposure as a percentage of original dry shear strength. The vertical bars indicate average percentages of wood failure. Each graph is usually based on several representative glues of one particular type. Since new glues have been added to the studies from time to time, however, the values shown for 1, 2, or 3 years' exposure are often based on a much larger number of glues than those shown for more extended exposure periods.

When continuously maintained at 80° F. and 65 percent relative humidity for 4 years (Fig. 1), the room-temperature-setting urea resins were the only glues tested that showed an appreciable decrease in average joint strength. This weakening was confirmed by a gradual drop in percentage of wood-failure values. At the end of 3 years' exposure, average joint strength of glues of this type conforming to Army–Navy Aeronautical Specification AN–G–8 (April 25, 1942) had decreased to about three-fourths of original values and had then retained approximately that level of strength for the next 12 months. Considerable difference, however, existed between individual glues. All other types of glues maintained high levels of strength throughout 3½ to 4 years of exposure to this mild condition.

[3] Room-temperature-setting urea-resin glues are cured with acid catalysts added to facilitate the setting action. Specification AN–G–8 limits acidity of these glues to a minimum pH of 2.5.

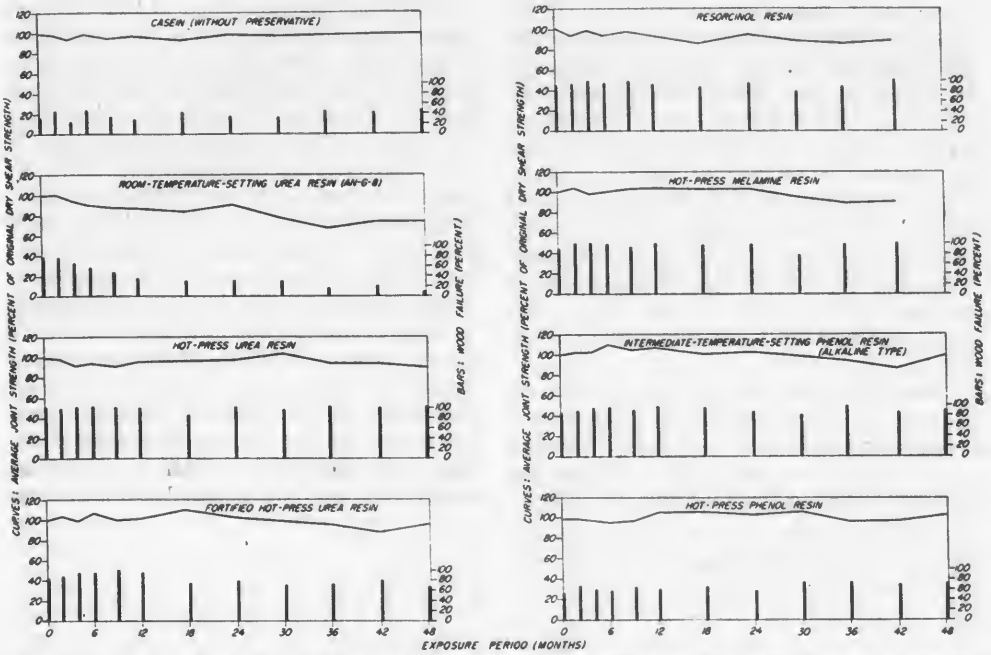
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 1.—Joint strength and wood failure of birch plywood specimens glued with eight types of glues and kept under continuous exposure at 80° F. and 65 percent relative humidity.

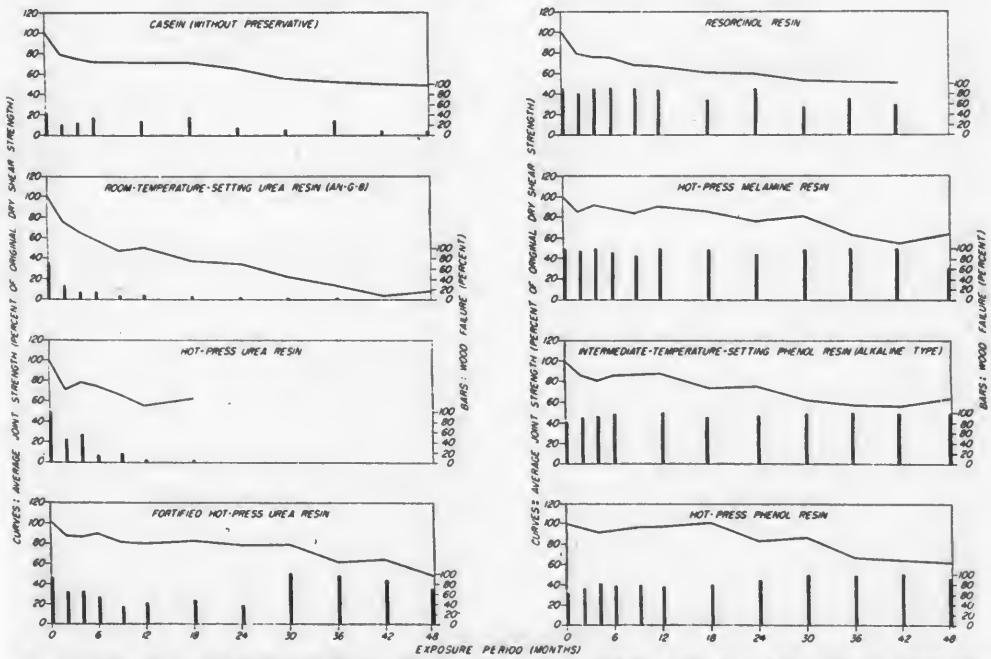
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 2.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed continuously at 158° F. and 20 percent relative humidity.

At 158° F. and 20 percent relative humidity (Fig. 2), room-temperature-setting urea resins showed a rapid decline in joint strength and percentage of wood failure and fell below 60 percent of the original strength within 6 months and to practically no strength after 3 to 4 years.

The hot-press ureas performed somewhat better, with about 60 percent of the original strength remaining after 18 months (longest period for which data are available), although the wood failures fell to about zero in this time, indicating that the glue bonds were deteriorating.

Casein and fortified hot-press urea had dropped to approximately the 50 percent strength level at the end of the exposure period of 4 years, but the wood failures showed no consistent trend, either increasing or decreasing. Consequently, a part of the loss in strength may have been caused by deterioration of the wood resulting from long-continued exposure to high temperature. Joints glued with phenol and melamine resins retained more than 60 percent of their original strength after 4 years' exposure, and resorcinol glue joints retained about 50 percent after 3½ years; all of these resin glues, however, maintained high percentages of wood failure, indicating deterioration of the wood rather than of the glue.

In other tests under still higher temperature conditions, namely exposure at 200° F. and 20 percent relative humidity *(11)*, both room-temperature-setting and hot-press urea-resin glue joints failed completely within a year. Fortified urea retained about 20 percent of the original strength at 18 months (duration of test period) and casein, resorcinol, melamine,

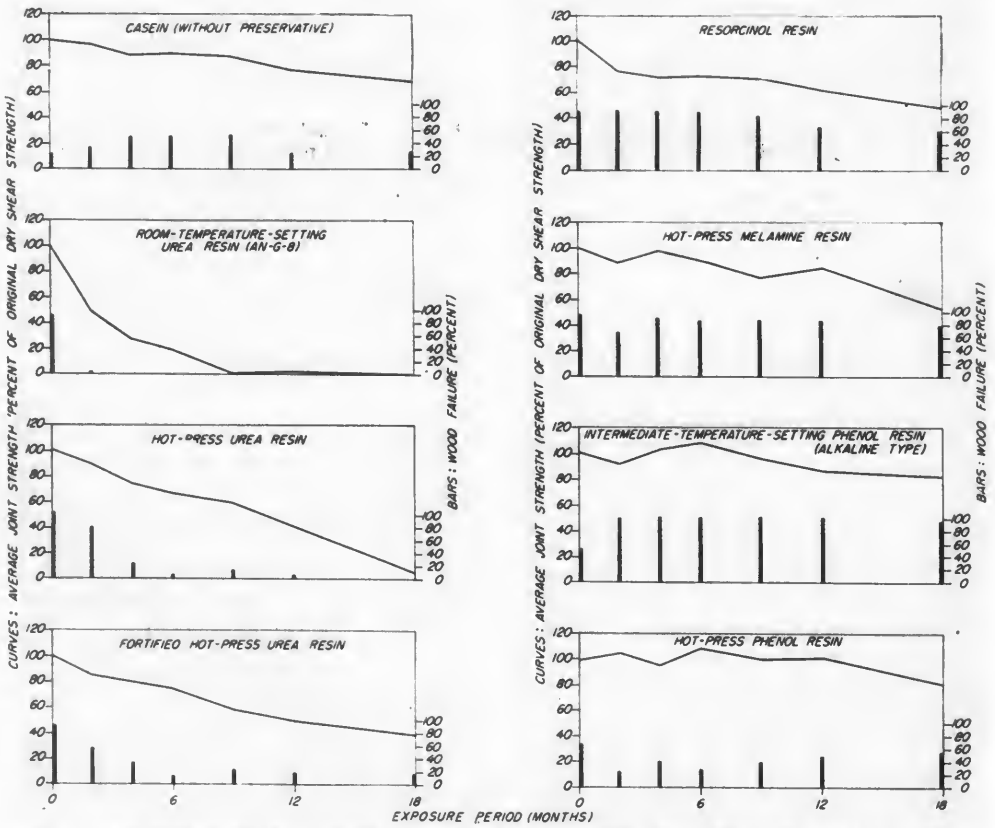
CASEIN (WITHOUT PRESERVATIVE)
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS UREA RESIN
FORTIFIED HOT-PRESS UREA RESIN
RESORCINOL RESIN
HOT-PRESS MELAMINE RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 3.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed continuously at 158° F. and 60 percent relative humidity.

and phenol-resin glues all had dropped to about 20 to 30 percent of their original strength in 30 months. The wood failure values, however, were generally high for all glues except the ureas, indicating that the wood was deteriorating at this exposure.

When subjected to flame tests *(8)* the component plies of plywood glued with casein and urea-resin glue (both hot-press and room-temperature-setting) separated as they were charred through, thus exposing fresh, unburned wood to the flames. When outer plies of phenol-resin-bonded plywood were charred, however, they did not separate, thus offering some protection to underlying layers of veneer and imparting some additional fire resistance. In common with phenol-resin-bonded plywood, the veneers of plywood bonded with resorcinol and melamine resin do not separate when exposed to fire *(5)*.

The higher moisture content prevailing under continuous exposure at 158° F. and 60 percent relative humidity (Fig. 3) caused a more rapid breakdown of room-temperature-setting urea-resin glue joints than exposure to 158° F. and 20 percent relative humidity. Within 2 months room-temperature-setting urea-resin glue fell below 50 percent of its original joint strength, and only a few specimens retained measurable joint strength at the end of 9 months. The only hot-press urea resin in these tests deteriorated less rapidly, but it had lost practically all strength after 18 months. Results obtained for as long as 18 months' exposure show considerable decrease in strength and wood failure of joints glued with some fortified hot-press ureas. Joints glued with alkaline intermediate-temperature-setting phenol, hot-press melamine, and resorcinol resins showed high average percentages of wood failure after various periods of exposure up to 18 months. Their declining strength appears to be caused primarily by the decreasing strength of the wood under this high temperature exposure. Although not characterized by generally high wood-failure values, joints glued with casein and hot-press phenol resin retained comparably high strength under this exposure.

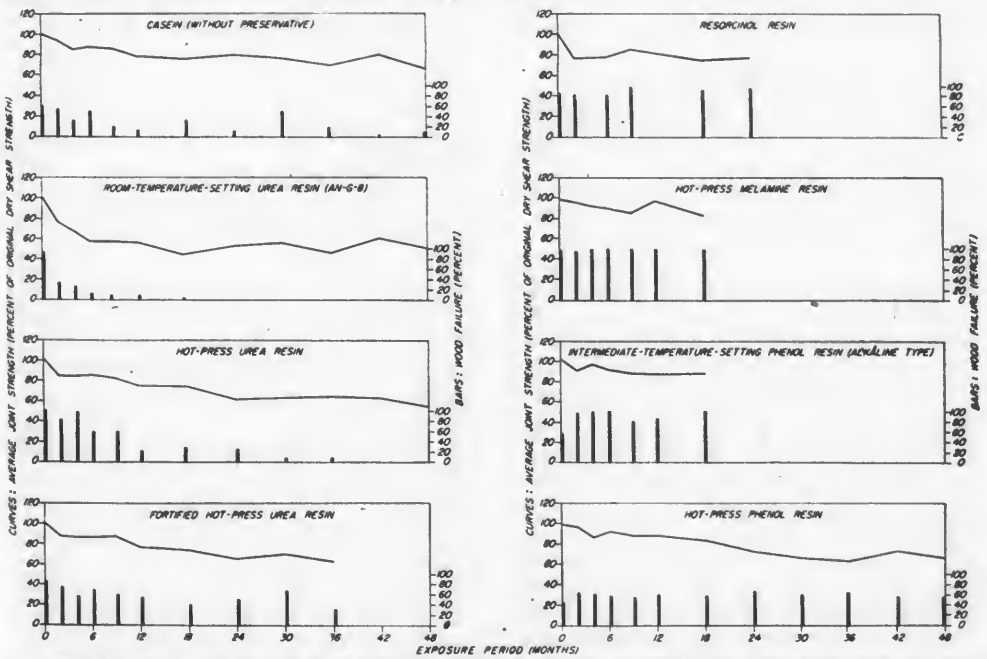
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 4.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed to a repeating cycle of 8 hours at 158° F. and 20 percent relative humidity followed by 16 hours at 80° F. and 65 percent relative humidity.

Exposure to a cycle of room and high temperatures (Fig. 4) caused joints glued with room-temperature-setting urea resin to lose considerable strength, especially during the early part of the exposure. Within 6 months, strength of the room-temperature-setting urea-resin glues dropped more than 40 percent and was accompanied by a gradual decline in wood failure. After 4 years of exposure, however, strength still averaged about 50 percent of the original. Joint strengths obtained with some fortified hot-press ureas and with hot-press urea resin decreased less, but they were accompanied by decreasing wood failure percentages over exposure periods ranging from 36 to 48 months. Casein glue joints decreased in strength at about the same rate as hot-press urea during the first 18 months of exposure, but after 4 years casein glue joints had retained about two-thirds of their original strength, whereas the hot-press urea joints had decreased nearly 50 percent. Hot-press and intermediate-temperature-setting phenol, resorcinol, and melamine glues retained high wood-failure values throughout exposure periods of 18 to 48 months, and joint strengths appear to be limited by the strength of the wood. Gradual weakening of wood takes place under these exposure conditions.

The cycle of room and low temperatures (Fig. 5) showed no outstanding difference in performance among the glues tested during 12 to 54 months of exposure as compared with the performance of joints exposed continuously to 80° F. and 65 percent relative humidity (Fig. 1). Most retained moderately high to high joint-strength values, although with the room-temperature-setting urea wood-failure percentages were negligible after 36 months, and after 54 months the strength had decreased to about 60 percent of the original. The fortified urea resins also developed practically no wood failure after 54 months of exposure, and at the end of this period their strength had dropped to about 70 percent of the original.

In the cycle of high and low relative humidity (Fig. 6), the intermediate-temperature-setting phenol, resorcinol, and hot-press melamine resins retained approximately 80 percent of their original strength after 4 years of exposure; and the hot-press phenols, for which data are available for a longer period, remained at this level even after 6 years. These glues maintained high percentages of wood failure

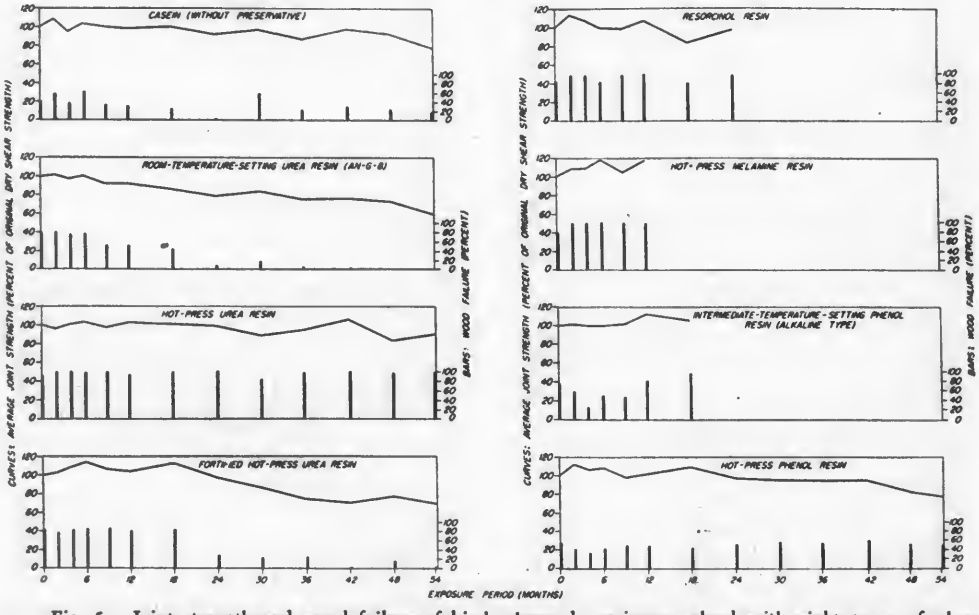
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 5.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed to a repeating cycle consisting of 8 hours at —20° F. followed by 16 hours at 80° F. and 65 percent relative humidity.

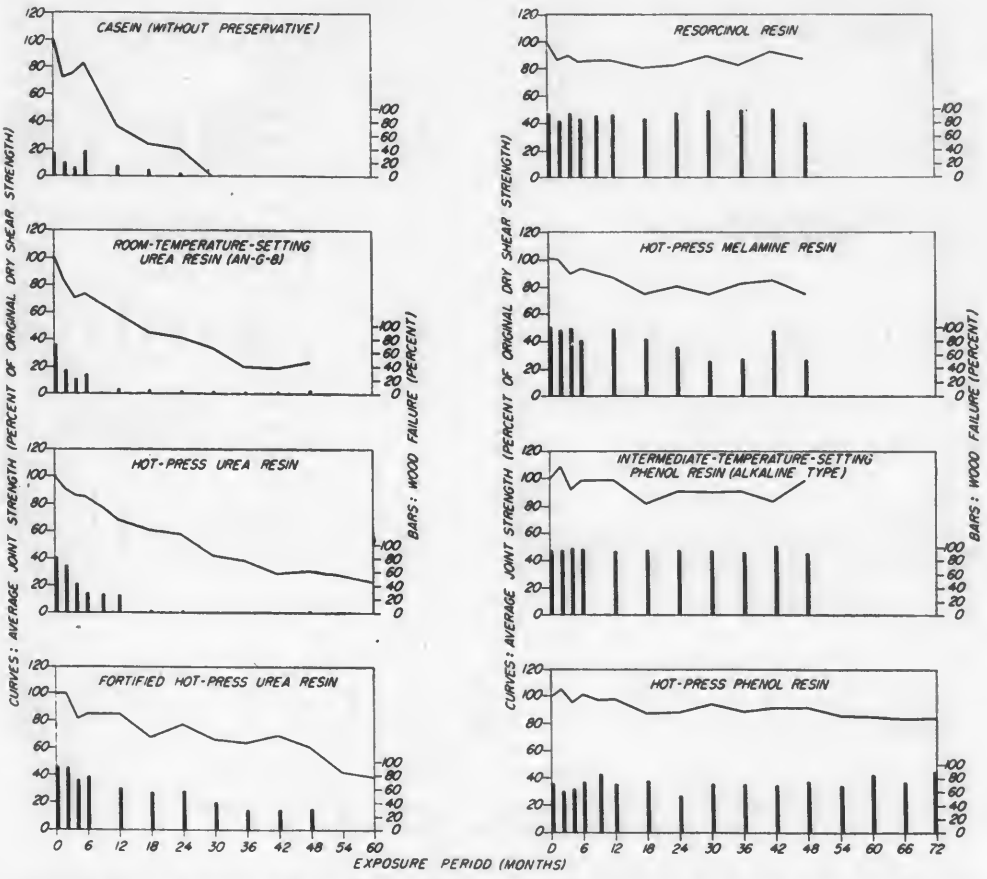
CASEIN (WITHOUT PRESERVATIVE)
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS UREA RESIN
FORTIFIED HOT-PRESS UREA RESIN
RESORCINOL RESIN
HOT-PRESS MELAMINE RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 6.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed to a repeating cycle consisting of 2 weeks in 97 percent relative humidity at 80° F., followed by 2 weeks in 30 percent relative humidity at 80° F.

under this exposure cycle. Casein glue failed rapidly, dropping below 40 percent of the original joint strength within 1 year. Room-temperature-setting urea-resin glue fell to approximately the 60 percent level within 1 year and to about 20 percent in 4 years. Decreasing percentages of wood failure indicated deterioration of the glue bond. The hot-press urea resins showed slightly better resistance to alternating high and low relative humidity conditions, but strength values dropped to less than 25 percent of the original in 5 years and after 18 months of exposure the wood failures were practically zero. The fortified hot-press ureas retained higher strength than the hot-press ureas, but some of them showed a gradual decline in wood-failure values throughout the exposure period.

Under continuous exposure to 97 percent relative humidity and 80° F. (Fig. 7), casein glue dropped below 40 percent of its original dry strength in 4 months and failed completely in 2½ years. Hot-press and room-temperature-setting urea resins fell to approximately the 60 percent level in 1 year but continued to show some measurable strength for several years. The hot-press ureas still retained a small percentage of their original strength after 7 years, although the room-temperature-setting urea resins failed completely in less than 5 years. The wood undoubtedly deteriorated under this severe exposure condition and contributed to

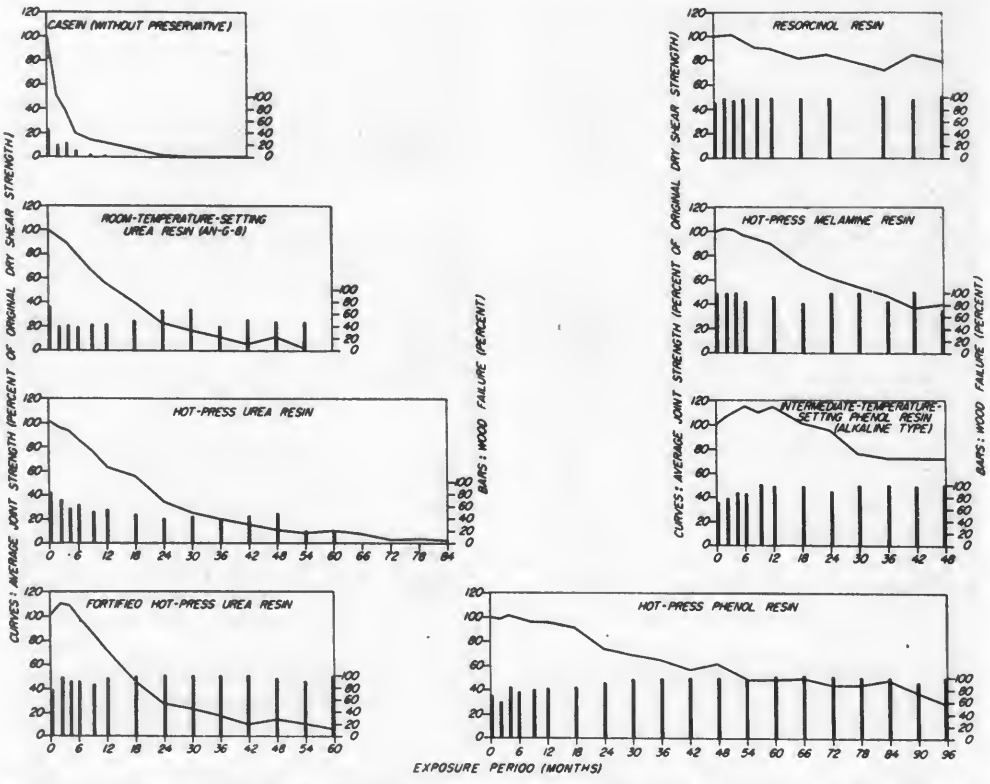
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 7.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues, under continuous exposure at 97 percent relative humidity and 80° F.

the reduction in joint strength shown; but decreased percentages of wood failure, particularly noticeable in the hot-press urea-resin glue joints after 4½ years of exposure, indicate that the glue bonds also broke down. Fortified urea-resin glue joint strength was about the same as for hot-press urea during 60 months' exposure, although wood failure of the fortified urea-resin joints remained very high. Up to 7 years of exposure, the hot-press phenol glue joints retained nearly 50 percent of their original strength, and the high percentages of wood failure throughout the entire 8-year test period indicate that joint strength was limited by the declining strength of the wood. The intermediate-temperature-setting phenol, resorcinol, and hot-press melamine glues all showed high wood failure throughout the 4-year exposure period and appear to be comparable to the hot-press phenol-resin glues, although the strength of the melamine-glued joints fell off somewhat more rapidly than that of the remainder of these glues.

During exposure to the cycle of soaking and drying (Fig. 8), casein glues failed rapidly, dropping below 40 percent of their original dry strength within 2 months. The room-temperature-setting urea glues dropped to about 60 percent of their original strength within 18 months and continued to lose strength throughout the 5-year exposure period. Decreasing strength was accompanied by very low wood-failure values. The hot-press and fortified hot-press urea resins maintained about 60 percent of original joint strength for 4½ years, but the rather consistent downward trend of wood failure values indicated that they were not quite so durable as the hot-press phenol resins. The hot-press phenol resins maintained a high level of wood failure throughout the

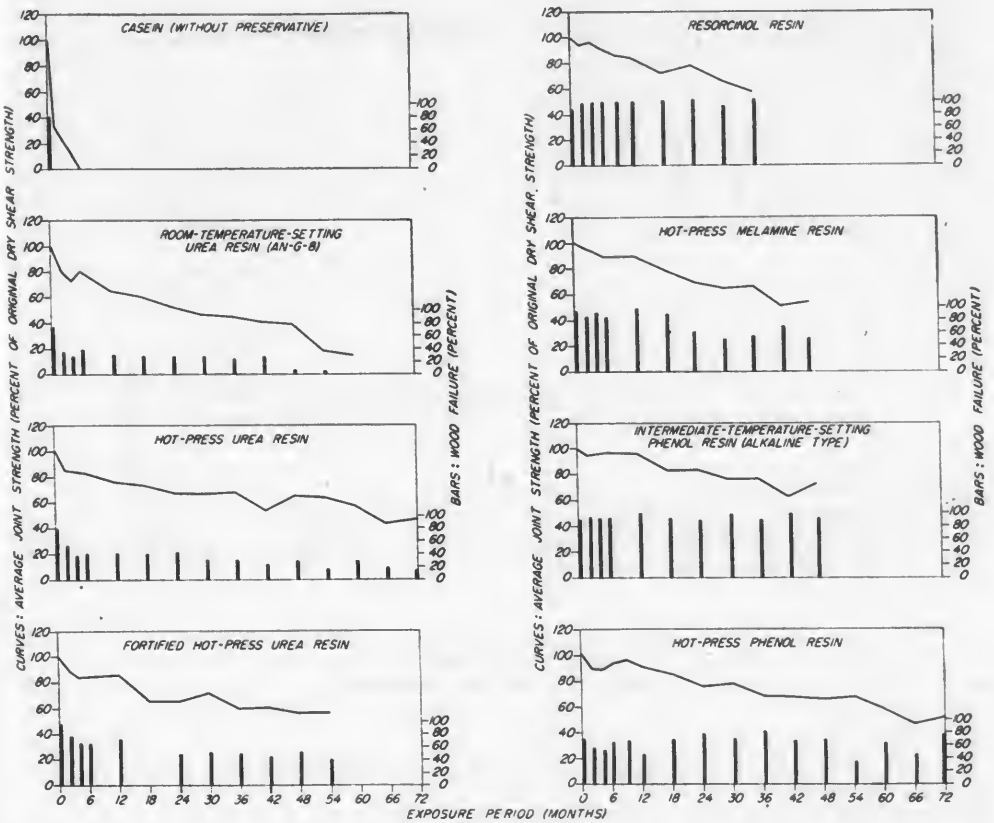
CASEIN (WITHOUT PRESERVATIVE)
RESORCINOL RESIN
ROOM-TEMPERATURE-SETTING UREA RESIN (AN-G-8)
HOT-PRESS MELAMINE RESIN
HOT-PRESS UREA RESIN
INTERMEDIATE-TEMPERATURE-SETTING PHENOL RESIN (ALKALINE TYPE)
FORTIFIED HOT-PRESS UREA RESIN
HOT-PRESS PHENOL RESIN
CURVES: AVERAGE JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)

Fig. 8.—Joint strength and wood failure of birch plywood specimens, glued with eight types of glues and exposed to a repeating cycle of 2 days' soaking in water at room temperature followed by 12 days' drying at 80° F. and 30 percent relative humidity.

6-year exposure period, indicating high durability of the glue. The resorcinol, intermediate-temperature-setting phenol, and hot-press melamine glues showed some decrease in strength, but wood failure remained high and these glues appear to be comparable to hot-press phenols in durability on the basis of the comparatively short periods for which exposure data are available.

Other types of exposures *(11)* have shown that, under continuous soaking in water at room temperature, casein glue failed in a relatively short time (no measurable strength after 18 months) while all types of synthetic-resin glues included maintained high wood failures and retained considerable strength throughout exposure periods ranging from 2½ to 6 years.

Durability of Casein Glue Containing Preservatives

Continuous or intermittent exposures to high humidity or to soaking were shown to result in rapid breakdown of casein-glued joints (Figs. 6, 7, and 8). In recent years, however, the introduction of casein glue to which preservative has been added has improved the effectiveness of these glues in preventing organic deterioration under exposures favorable for the growth of molds and other microorganisms *(6)*. The improvement in mold resistance obtained with such preservatives added to two commercial casein glues is shown in Fig. 9. The glues to which preservative had been added retained about 50 percent of their strength after 15 months' exposure, whereas

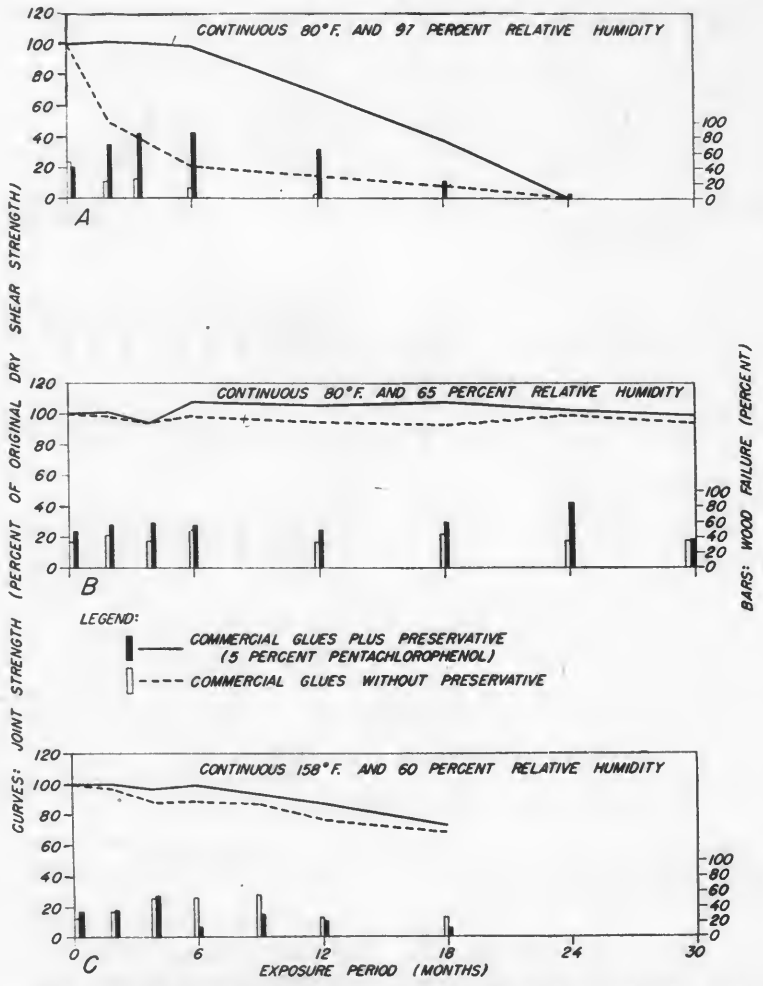
CONTINUOUS 80°F. AND 97 PERCENT RELATIVE HUMIDITY
CONTINUOUS 80°F. AND 65 PERCENT RELATIVE HUMIDITY
CONTINUOUS 158°F. AND 60 PERCENT RELATIVE HUMIDITY
A
B
C
CURVES: JOINT STRENGTH (PERCENT OF ORIGINAL DRY SHEAR STRENGTH)
BARS: WOOD FAILURE (PERCENT)
EXPOSURE PERIOD (MONTHS)
LEGEND:
COMMERCIAL GLUES PLUS PRESERVATIVE (5 PERCENT PENTACHLOROPHENOL)
COMMERCIAL GLUES WITHOUT PRESERVATIVE

Fig. 9.—Joint strength and wood failure of birch plywood specimens, glued with different casein glue, with and without the addition of pentachlorophenol under (A) continuous exposure at 80° F. and 97 percent relative humidity, (B) continuous exposure at 80° F. and 65 percent relative humidity, and (C) continuous exposure at 158° F. and 60 percent relative humidity.

the strength of the unpreserved glues had dropped to this level in 2 months *(9A)*. In 2 years, however, the joint strength of both types had dropped to zero, which would indicate that even with preservative added casein glue has considerably less resistance to high humidity than the more durable resin glues (Fig. 7). Evidence that the effectiveness of casein glue to which a preservative has been added is not appreciably changed at normal or elevated temperature is given in Fig. 9 (B and C), based on exposure of the same commercial glues at 80° F. and 65 percent relative humidity for 30 months and at 158° F. and 60 percent relative humidity for 18 months.

Although evidence obtained from 48-hour soaking tests indicates that the resistance of casein glues to short periods of soaking is not consistently improved by the addition of preservatives, disinfected casein-glued specimens have been found to resist continuous soaking in water better than specimens that were much

more easily attacked by bacteria when similarly exposed. The possibility is indicated that some improvement may result from using preservatives that are effective against bacteria *(4)*. Results of prolonged periods of soaking or soaking-drying cycles for casein glues containing preservative indicate that their resistance to these exposures is not widely different from that of ordinary casein glues.

Exposure of Joints Between Plywood and Framing Members Under Controlled Conditions

Plywood glued to solid wood framing members is the basic building unit in some of the most widely used prefabricated housing systems. In this unit, incorporating the stressed-cover or stressed-facing principle, the plywood as well as the framing carries a load and the strength of the unit is dependent to a large extent upon the joint strength between the plywood and the framing.

A study, covering a 10-year period, was made to develop information on the performance of glue joints between plywood and solid members when exposed to conditions simulating service of various degrees of severity.

Test Procedure

Phenol-bonded Douglas-fir plywood panels 12 by 12 inches in area and 1/4 or 5/8 inch in thickness were glued to nominal 1- by 2-inch or 2- by 3-inch Douglas-fir framing. Two framing members, arranged in T-shape, were glued to each panel. The grain of one member was perpendicular and that of the other parallel to the grain of the face ply. Glues used were casein to which a preservative (beta naphthol) had been added, room-temperature-setting urea resin, and hot-setting phenol resin (alkaline type).

Nails or a screw press were used to apply gluing pressure (except for the hot-setting phenol, which was hot pressed).

Each specimen was subjected to one of the following cyclic exposures repeated for a period of 10 years:

1. A month in 65 percent relative humidity where the moisture content of the specimens would approach the 12 percent level, followed by 1 month in 30 percent relative humidity (equilibrium moisture content about 6 percent).
2. A month in 80 percent relative humidity (approaching 16 percent in moisture content) followed by 1 month in 30 percent relative humidity (drying to 6 or 7 percent moisture content).
3. A month in 90 percent relative humidity (equilibrium moisture content about 20 percent) followed by 1 month in 65 percent relative humidity (drying to about 12 or 13 percent).
4. A month in 97 percent relative humidity (where the moisture content of the specimens would rise considerably above 20 percent) followed by 1 month in 30 percent relative humidity (drying to 6 or 7 percent).

The temperature in all exposures was 80° F.

At intervals throughout the exposure period, shear specimens were cut from the panels for tests on the joints between the plywood and the T frame. The number of specimens taken with the face grain of the plywood parallel to the framing member was equal to the number having the face grain perpendicular to the framing member. The conventional block-shear method was used, and backing strips were glued to the side of the plywood opposite the framing member to prevent the plywood from failing in compression. A number of the specimens were tested without being subjected to any exposure to obtain control test values. In the graphical presentation of the results (Fig. 10) the test values after various exposures are expressed as a percentage of those of the controls. Since the results from joints in which the grain of the framing members was parallel to the face grain of the plywood varied considerably from the results with joints where the grain of the framing members was perpendicular to the face grain of the plywood, the data for the two types are shown separately.

Results of Tests

The general application of the results of this study is somewhat limited, because no temperatures higher than 80° F. were involved in any of the exposure conditions and Douglas-fir was the only species included.

As pointed out previously, temperatures well in excess of 80° F. can be expected in housing panels under normal service conditions. If exposures to temperatures in the neighborhood of

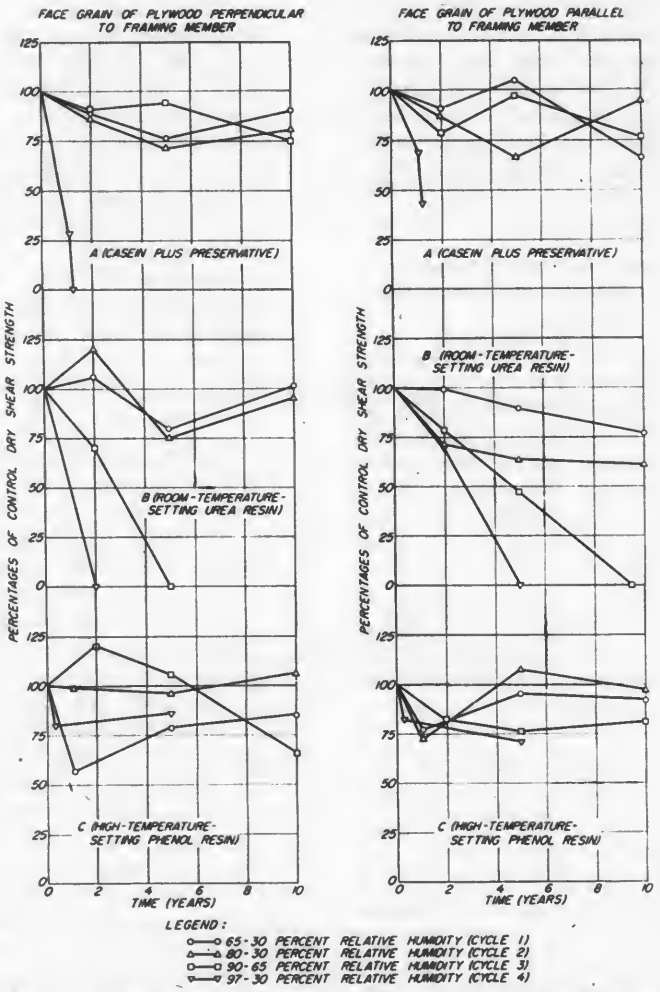
FACE GRAIN OF PLYWOOD PERPENDICULAR TO FRAMING MEMBER
FACE GRAIN OF PLYWOOD PARALLEL TO FRAMING MEMBER
A (CASEIN PLUS PRESERVATIVE)
B (ROOM-TEMPERATURE-SETTING UREA RESIN)
C (HIGH-TEMPERATURE-SETTING PHENOL RESIN)
PERCENTAGES OF CONTROL DRY SHEAR STRENGTH
TIME (YEARS)
LEGEND:
65-30 PERCENT RELATIVE HUMIDITY (CYCLE 1)
80-30 PERCENT RELATIVE HUMIDITY (CYCLE 2)
90-65 PERCENT RELATIVE HUMIDITY (CYCLE 3)
97-30 PERCENT RELATIVE HUMIDITY (CYCLE 4)

Fig. 10.—Shear strength of glue joints between plywood and framing members after various periods of one of the different cyclic exposures.

150° F. had been included, a significantly different performance, especially of the urea-resin glue joints, would be expected (based on the results with birch plywood).

Joints fabricated by using nails to apply gluing pressure appeared to be less reliable than joints made in screw presses. Evidence in favor of positive methods of applying gluing pressure was most consistent from the results of joints made with room-temperature-setting urea resin exposed to severe test conditions; the difference was less marked in the results of tests on joints made with casein glue.

Resistance of glue joints between plywood and framing members glued with three glues and subjected to four different exposure conditions is shown in Fig. 10. Where no results are shown up to and including 10 years' exposure, and complete failure is not indicated by the last results shown, the number of specimens made was insufficient to provide test material for the entire 10-year period.

Casein glue with preservative (beta naphthol) maintained its strength reasonably well in all exposures except in the cycle of high and low humidity (97 percent relative humidity

followed by 30 percent relative humidity), in which it failed quite rapidly.

Room-temperature-setting urea maintained from 60 to 100 percent of its original strength in the two milder exposures (65 to 30 and 80 to 30 percent relative humidity) but showed a steady and rather rapid decline where the exposures involved higher humidities. In the cycle of 97 and 30 percent, the joint strength was reduced to zero within 2 to 5 years.

The hot-press phenol glue joints performed well in all cyclic exposures and even in the 97 to 30 percent exposure the strength was 70 percent or more of the original after 5 years (the longest exposure of this cycle for phenol-glued specimens).

Weathering Tests on Plywood Panels

Plywood panels exposed unprotected to the weather (Fig. 11) have provided evidence of the durability of several types of adhesives under the variable conditions of outdoor exposure. Plywood test panels, 18 inches square, constructed of different species and different thicknesses of veneer, were exposed up to 11 years, although for glues of more recent development the exposure periods are much shorter. An equal number of yellow birch, yellow-poplar, and Douglas-fir panels were included in these tests. Three-ply panels were made from $\frac{1}{16}$-inch veneer and five-ply from $\frac{1}{8}$-inch veneer. Each panel was visually inspected at regular intervals and rated on the basis of the integrity of the glue joints. The percentage of joint area open and the percentage of wood failure were considered in arriving at the rating of each glue type shown in Fig. 12.

Of the glues for which data are available over a long period of years, the hot-press and intermediate-temperature-setting phenols showed the highest degree of durability. In the order of decreasing durability, the other glue types included were as follows: hot-press urea resin, room-temperature-setting urea resin conforming to Specification AN–G–8, and casein (without preservative). The casein glues had dropped to a 50 percent integrity rating level in about $2\frac{1}{3}$ years, the room-temperature-setting ureas had dropped to this level in 4 years, and the hot-press ureas in $5\frac{3}{4}$ years. The trend indicated by the curves, however, points to the conclusion that within a span of 10 years or less each of these three types of glues will have reached a very low integrity rating.

The exposures for plywood glued with resorcinol, melamine, and fortified urea resin

Fig. 11.—Forest Products Laboratory plywood weathering test fence.

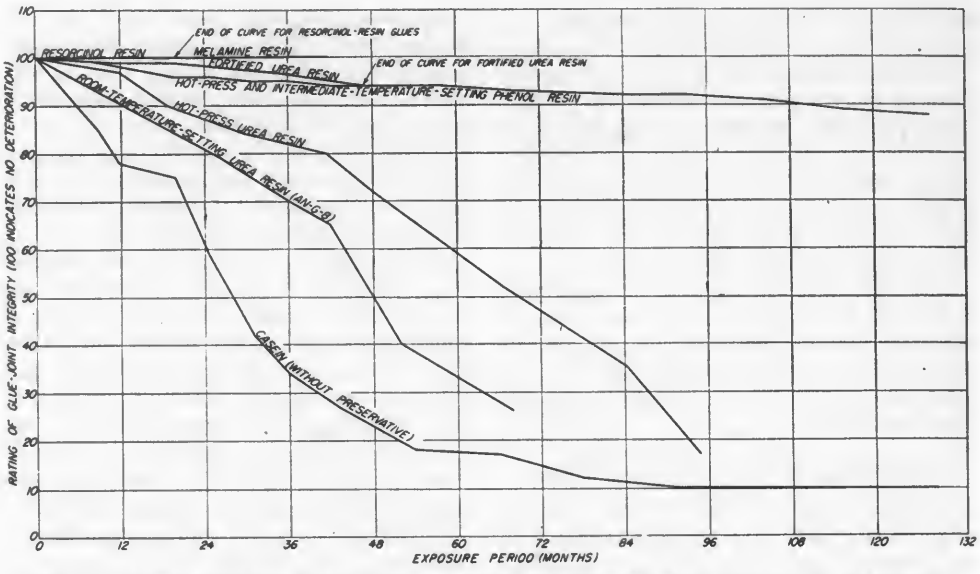

Fig. 12.—Relative durability of glued joints in unprotected plywood panels subjected to weathering.

have run about 20, 42, and 48 months respectively. During the period of exposure, the resorcinols and melamines have maintained 100 percent glue-joint integrity and the fortified ureas have decreased only a slight amount. A comparison of the performance of these glues with that of others for similar periods of exposure would indicate that good durability can be expected of resorcinol, melamine, and probably also of fortified urea-resin glues.

Exposure Tests on Laminated Beams

Exposure of beams laminated from nominal 1-inch lumber has proved to be a dependable method for determining the durability of glues. More than 8 years ago casein and room-temperature-setting urea resin were used to glue Douglas-fir and southern yellow pine beams 7 by 7 inches in cross section and about 5 feet long, consisting of nine laminations of nominal 1-inch lumber. The beams were glued at approximately 12 percent moisture content and subjected to several conditions, including outdoor exposure and exposure in an unheated shed. At intervals sections were removed from the ends of these beams and cut into block-shear specimens that were tested, after conditioning to approximately 12 percent moisture content, to determine the strength of the glued joints.

During the early part of World War II, extensive studies were begun to determine the suitability of various glues for laminating white oak, Douglas-fir, and southern yellow pine for use under exterior conditions. Several hundred beams 4 feet long and 6 by 6 or 8 by 10 inches in cross section were laminated with resorcinol, intermediate-temperature-setting phenol, and intermediate-temperature-setting melamine-resin glues and cured at various temperatures. Sections from these beams were tested in the dry condition (about 12 percent moisture content) to determine the original shear strength of the glue joints. The beams themselves were exposed outdoors or immersed in salt water without protection except that one end was painted. At intervals a short section was removed from the painted end to provide material for shear testing and the cut end was repainted before further exposure. The shear specimens were conditioned to 12 percent moisture content before being tested. The unpainted end of the beam was inspected regularly for evidence of delamination.

Results of Laminated Beam Exposure Tests

Exposure to covered, unheated conditions.—Shear-test results of joints made with casein (without preservative) and room-temperature-setting urea resin exposed to covered, unheated

conditions for periods up to 8 years are given in Table 1. Under these conditions, both types of glue maintained high joint strength and wood failure on the two softwood species involved throughout the exposure period and there was no indication of deterioration in bond quality with prolonged exposure with either glue.

TABLE 1.—DURABILITY OF JOINTS IN UNPAINTED, LAMINATED BEAMS EXPOSED TO COVERED, UNHEATED CONDITIONS

Exposure period	Southern yellow pine		Douglas-fir	
	Average shear strength	Wood failure	Average shear strength	Wood failure
Months	p.s.i.	Percent	p.s.i.	Percent
Casein without preservative				
0	1,584	91	1,751	97
6	1,603	93	1,560	98
12	1,729	70	1,795	95
18	1,821	86	1,932	88
30	1,559	88	1,698	90
48	1,589	86	1,522	98
60	1,612	84	1,424	92
96	1,596	84	1,648	91
Room-temperature-setting urea resin				
0	1,465	84	1,569	97
6	1,654	96	1,500	94
12	1,851	96	1,627	98
18	2,014	85	1,757	85
30	1,663	97	1,578	93
48	1,774	92	1,596	92
60	1,718	93	1,287	94
96	1,814	96	1,600	82

TABLE 2.—DURABILITY OF JOINTS IN UNPAINTED, LAMINATED BEAMS UNDER OUTDOOR EXPOSURE

Exposure period	Southern yellow pine		Douglas-fir	
	Average shear strength	Wood failure	Average shear strength	Wood failure
Months	p.s.i.	Percent	p.s.i.	Percent
Casein without preservative				
0	1,735	96	1,791	94
6	944	52	1,487	99
12	1,253	70	1,525	85
18	1,564	76	1,593	77
30	444	21	1,394	97
48	0	0	1,300	97
60	-----	--	1,224	80
96	-----	--	1,259	87
Room-temperature-setting urea resin				
0	1,423	83	1,664	100
6	1,051	73	1,096	100
12	1,075	71	1,056	100
18	1,294	89	1,277	88
30	762	77	871	89
48	480	56	861	82
60	462	39	640	62
96	0	0	774	73
Resorcinol–resin glue[1] cured at 80° F.				
0	1,857	82	1,451	93
4	1,645	82	1,359	91
8	1,683	83	1,311	91
12	1,723	84	1,334	91
36	1,671	91	1,351	93
Intermediate-temperature-setting phenol–resin glue[1] cured at 80° F.				
0	2,051	71	1,638	89
4	1,625	73	1,353	87
8	1,674	73	1,340	89
12	1,670	79	1,390	88
36	1,691	86	1,187	96

[1]These results are averages for several beams each glued with a different formulation of this type of glue.

Exposure to outdoor conditions.—Under outdoor exposure, casein and urea-resin glue bonds deteriorated gradually, as shown in Table 2. In southern yellow pine, joints glued with casein and urea resin deteriorated in a similar manner, although the urea-glued joints retained a measurable strength longer than did the casein joints. In Douglas-fir, casein performed markedly better than urea. In 8 years the urea-glued joints in Douglas-fir had dropped to less than 50 percent of their original strength, whereas the casein-glued joints had retained about 70 percent.

A comparison of results for the two species (Table 2) shows that the joints in Douglas-fir were somewhat more durable than those in southern yellow pine when glued with either casein or urea resin, and especially so when glued with casein. This difference may have been due to differences in moisture content observed throughout the period of exposure. Although all beams were glued at approximately 12 percent moisture content, the range of moisture content throughout the period varied: for southern yellow pine from about 14 to 30 percent and for Douglas-fir from about 12 to 19 percent. The higher moisture content in the pine beams favors the development of molds and other micro-organisms known to be detrimental to casein glue and possibly also to urea-resin glues.

Results of visual examination of the beams showed that considerable delamination developed in some of the joints after only a few months of exposure, although other joints were intact and maintained high shear values. Even though the average shear strength of the Douglas-fir beams glued with casein (which were the most durable) was high after 8 years of exposure, considerable delamination had developed in the beams.

Results of the studies to determine the suitability of glues in laminating for exterior service indicated that resistance to delamination on outdoor exposures is a more critical test of glue-joint durability than retention of shear strength under continuous soaking in either fresh or salt water *(10)*. These studies also established the need for higher bond quality to develop maximum resistance to delamination in laminated oak members than is indicated by plywood tests. The studies showed further that

various degrees of cure may be required with resin glues to develop bonds adequately durable for exterior service depending upon the species being bonded. When gluing white oak, for example, with intermediate-temperature-setting phenol resin for exterior use, a curing temperature of 190° F. maintained for about 10 hours was found to be necessary. When used on a softwood species such as Douglas-fir, however, adequate bond for outdoor use was obtained with these glues at a curing temperature of 80° F. maintained for about 20 hours *(7)*. Resorcinol resins produced adequate bonds for exterior use in white oak when cured at 140° F. and similar durability with joints in softwoods was obtained when these glues were cured at temperatures ranging from 70° F. to 80° F.

Results of shear tests on Douglas-fir and southern yellow pine beams glued with resorcinol and intermediate-temperature-setting phenol-resin glues and exposed unprotected to the weather are given in Table 2. There was generally a slight decrease in strength with extended exposures which was probably due to checking and weakening of the wood, but in no case was there any falling off in wood failure, indicating that the glue bond strength was maintained without deterioration.

Fig. 13 shows a 6- by 6-inch Douglas-fir beam glued with an intermediate-temperature-setting phenol-resin glue and exposed to the weather for 3 years. The wood had checked considerably, but there was no appreciable glue-joint failure although the checks were in some cases close to the joints. An oak beam made with a similar type of glue but cured at 190° F. is shown in Fig. 14. This beam was 8 by 10 inches in cross section and had been exposed to the weather for 4 years when the picture was taken. In this beam, also, considerable checking had developed, indicating that severe stresses had been exerted on the joints; nevertheless, the joints were almost entirely free from glue failure.

The beams shown in Figs. 13 and 14 are typical of a large number of specimens glued

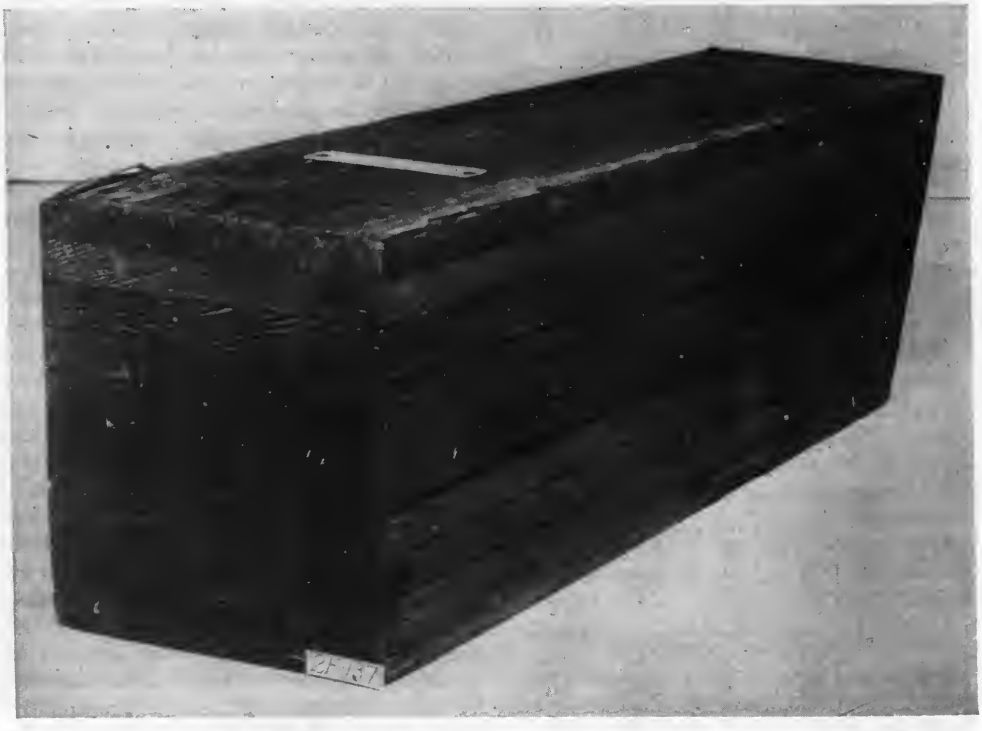

Fig. 13.—Douglas-fir beam glued with an intermediate-temperature-setting phenol cured at 80° F. and exposed unprotected to the weather for 3 years.

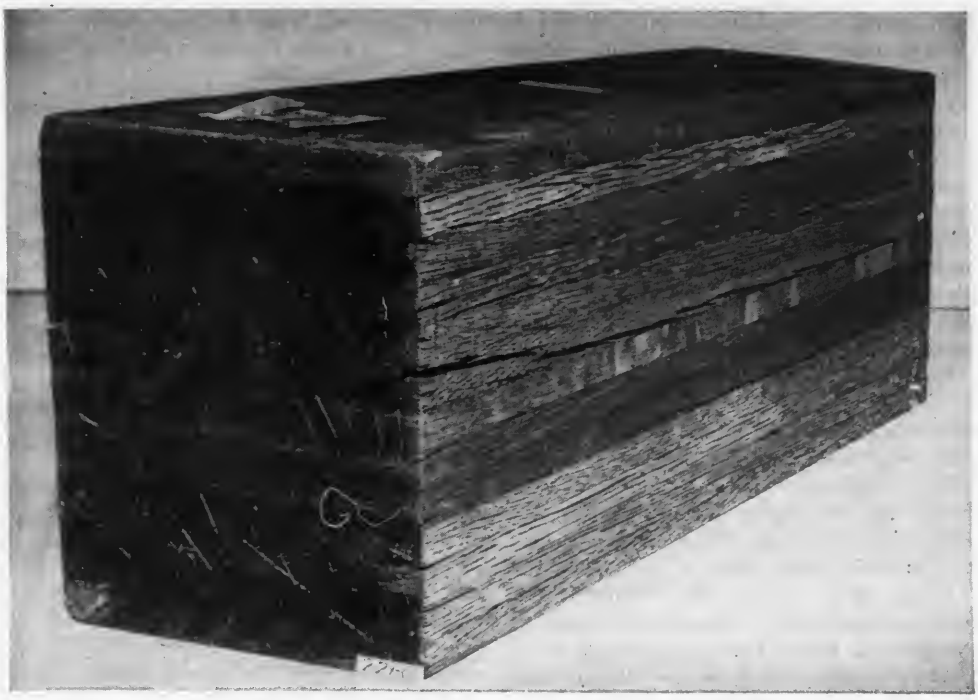

Fig. 14.—Laminated white oak beam glued with an intermediate-temperature-setting phenol cured at 190° F. and exposed unprotected to the weather for 4 years.

with intermediate-temperature-setting phenol-, melamine-, or resorcinol-resin glues and similarly exposed, and their performance indicates that glue joints made with these glues are as durable as the wood in any type of service when well made.

Summary and Recommendations

With certain types of glues there is definite deterioration of the bond as the exposure becomes more severe either in temperature or moisture conditions, while others appear to maintain a bond equal to the strength of the wood under any type of exposure.

Casein glue (unpreserved) performed well in all tests where protection from high humidity or direct wetting was afforded. Under outdoor conditions, however, or where high humidities, either continuous or intermittent, were involved, casein glue joints failed. Casein glue containing preservative showed greater resistance to high humidities than unpreserved casein, but did not attain the permanence of the more durable resin glues under conditions favoring mold growth. The addition of a preservative retarded but did not prevent destruction of casein glue bonds under damp conditions. Consequently, casein glue is not considered suitable for exterior use in house construction or for interior use where the moisture content of the wood may be expected to exceed about 20 percent for repeated or prolonged periods.

Room-temperature-setting urea-resin glues showed greater resistance to intermittent soaking than casein glue. Where high temperature or high humidity, and especially a combination of the two, was involved, however, urea-resin glue joints failed. In laminated construction on softwoods, urea-resin glue joints retained their original strength throughout an 8-year period of exposure in an unheated open shed but failed or weakened seriously with the same species in much less time when exposed unprotected outdoors. Urea glue joints between plywood and framing members (both Douglas-fir) failed in less than 10 years when exposed intermittently to 90 percent relative humidity (mois-

ture content approaching 20 percent) and 65 percent relative humidity (moisture content approaching 12 percent) at a constant temperature of 80° F. In the mild exposure of 65 percent relative humidity and 80° F., urea resin was the only one among eight types of glues tested to show a definite decrease in both strength values and percentage of wood failure over the period investigated. Hence the data available on the performance of urea-resin glue joints under conditions of service comparable to those that are likely to be encountered in a house cast doubt on their suitability for use in permanent house construction.

Hot-setting urea resins in general have shown somewhat better durability than the room-temperature-setting ones. Their resistance to high temperature and high humidity, however, is not sufficient to establish their serviceability for uses where long-term permanence, such as house construction, is required.

Joints made with fortified hot-press urea resin in general are more durable than the straight urea resins, but under certain conditions of exposure they are less durable than phenol, melamine, and resorcinol resins.

Tests on phenol-resin glue joints up to about 10 years have proven their permanence under any conditions where wood is a suitable material. Since melamine and resorcinol-resin glue joints have performed similarly to those made with phenols during the time they have been undergoing tests, it is reasonable to expect that they are similar to the phenols in permanence. The durability and low-temperature curing characteristics of resorcinols and certain phenol-resorcinol combinations (often marketed as intermediate-temperature-setting phenols) make these glues superior to other adhesives available for constructions where the choice of glue is limited to those that set at room temperature.

Literature Cited

(1) Blomquist, R. F.
1944 Effect of High and Low Temperatures on Resin Glue Joints in Birch Plywood. Forest Products Laboratory Report No. 1345.

(2) Brouse, Don
1938 Controlled Exposure Tests on Birch Plywood Indicate Durability of Water-Resistant Glue Joints. Forest Products Laboratory Report No. 1185.

(3) Browne, F. L., Downs, L. E., Laughnan, D. F., and Schwebs, A. C.
1944 Study of Temperature and Moisture Content in Wood Aircraft Wings in Different Climates. Forest Products Laboratory Report No. 1597.

(4) Christensen, Clyde M. and Moses, C. S.
1945 Molds and Bacteria That Delaminate Plywood Bonded With Casein and Soybean Glues. Bureau of Plant Industry, Soils, and Agricultural Engineer, Forest Pathology Release No. 25.

(5) Forest Products Laboratory
1948 Synthetic-Resin Glues. Forest Products Laboratory Report No. 1336.

(6) Kaufert, F. H.
1943 Increasing the Durability of Casein Glue Joints With Preservatives. Forest Products Laboratory Report No. 1332.

(7) Knauss, A. C. and Selbo, M. L.
1947 Manual on the Laminating of Structural Timber Products by Gluing. Forest Products Laboratory Report No. R1635.

(8) McNaughton, G. C. and Harrison, C. A.
1940 Fire-Resistance Tests of Plywood Covered Wall Panels. Forest Products Laboratory Report No. 1257.

(9) Peck, E. C.
1932 Moisture Content of Wood in Dwellings. United States Department of Agriculture Circular No. 239.

(10) Truax, T. R. and Selbo, M. L.
1948 Results of Accelerated Tests and Long Term Exposures on Glue Joints in Laminated Beams. Transactions of A.S.M.E. Volume 70, No. 4.

(11) Wangaard, F. F.
1946 Summary of Information on the Durability of Woodworking Glues. Forest Products Laboratory Report No. 1530.

Radio Frequency Application Problems of Furniture Manufacturers*

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President, Woodwelding, Inc., Burbank, California

The contribution of high frequency heating techniques to the production of furniture is becoming more generally recognized. It is the purpose of this paper to describe and illustrate the application of various high frequency heating techniques in the production of various furniture items by a number of manufacturers.

Introduction

A PROGRAM of research with the objective of achieving superior low cost production has been undertaken in many furniture manufacturing plants recently. The furniture manufacturer renders a great service to the buying public by creating or causing the creation of new production assembly tooling to offset the increased cost of labor and materials.

The woodworking machinery manufacturers and other engineering consultants combine their experience with the furniture manufacturer to design and construct ways and means for cost reduction by increasing speed of production and reducing man hours for assembly operations.

The furniture manufacturer offsets the loss of skilled workers by the use of precision mechanical and electronic equipment that may be operated by less skilled men to produce a superior quality product. This change seems to be natural because new methods and materials bring forth a craftsman whose lack in knowledge of hand carving and hand fitting of component assemblies are offset by a scientific knowledge of production methods and tool design.

Radio Frequency Application Problems as Solved by a Few Furniture Manufacturing Firms

Example 1

The problem of furniture manufacturer A was to prevent increased labor and material costs from reflecting in retail sales price of a bedroom chest. The manufacturing requirements being 500 chests per day called for strategic planning by the manufacturer.

The chest end was designed for automatic shaper operation upon removal from high frequency press and conveyor line, thus eliminating dual handling costs and humidified room storage. It has been proven that the desired equilibrium moisture content can be held to plus or minus one-half of one percent by high frequency assembly, deleting the humidity controlled storage room.

Material costs could not be reduced and maintain a high quality standard. Staining and finishing methods were of the highest quality, and no labor or material cost reduction was available in this department.

The designer for the company suggested redesigning the chest for greater appeal and at the same time for rapid production assembly in an automatic woodwelder high frequency press. Having used the smaller portable Woodwelder in satisfactory production for a period of 3 years, it seemed logical that a higher powered Woodwelder coupled to an automatic hydraulic pressure assembly jig would solve the problem because time study had shown this to be the only means of lowering production costs and not quality. Fig. 1 shows the chest-end assembly-press, which is capable of producing 1000 chest ends per day with a resultant labor saving to prevent price increase.

Example 2

The problem of furniture manufacturer B was to assemble miter joints on a production basis, fabricating 200 assemblies per day with no rejection caused by joint slippage or unequal pressure.

The owner of the company takes pride in designing outstanding furniture pieces and in doing so demands of his workmen quality

* Presented by title only.

assembly and finishing. The miter joint design called for high cost production by standard methods of assembly of designing production tooling to lower man hours of assembly time. The latter was decided upon, and Fig. 2 depicts the universal case clamp and Woodwelder electrodes incorporated therein. The Woodwelders were first used by this company in the early war years on aircraft production. The manufacture of the invasion glider and radio television controlled glide bomb were the outstanding achievements of this company. They have continued use of the Woodwelder since that time on furniture and radio console manufacture.

Example 3

The problem of furniture manufacturer C was the repair of damaged furniture, which often required replacement of full panels and a large floor space for repairs. This same type of damage frequently resulted in delay of shipment.

This problem, encountered by all furniture manufacturers, was solved first by this concern nearly four years past when they purchased their first Woodwelder and were able to make repairs without removing furniture from the conveyor line. Fig. 3 shows the hand gun and Woodwelder in use repairing chipped veneer.

Deep dents in wood may be removed by applying a few drops of water in a dent and applying a fibreglass shoe electrode to surface. Instant steaming will allow the wood fibers to return to their natural position.

Example 4

The problem of this manufacturer was the assembly of miter joints and edge banding with thin veneer to produce an outstanding piece of modern furniture as shown in Figs. 4A and 4B without the use of nails and screws, as nails are used only in lower quality furniture.

They solved their assembly problem by use of a case clamp shown in Fig. 4C. This clamp, operating with adjustable air cylinders, clamps electrodes to all miter corners for adequate pressure and curing glue line at the same time with stray field electrodes.

Example 5

The problem of this concern was to complete and install all furniture and fixtures in a new department store during the period of shortage of lumber and plywood. This $500,000 contract job with date of completion specified and guaranteed was completed on schedule when the contractor discovered that Woodwelding dielectric equipment would come to the rescue after scarce plywood and lumber arrived.

Furniture and fixtures of the type shown in Fig. 5 were assembled, installed and finished on the job as the building was being constructed. A case clamp similar to that shown in Fig. 4C was used for assembly of ¾-inch plywood miter joint cases where drawer slides and drawers were installed upon removal from case clamp and were followed by lacquer finishing group. A saving of $90,000 resulted from the use of the Woodwelders and proper tooling.

Example 6

Problem encountered by a manufacturing concern of Milano, Italy:

Inlaying craftsmanship in Italy is unexcelled, but cost reduction was necessary to meet world wide competition of other furniture designs. Mass production of inlaid furniture was unknown until the firm installed Woodwelders and tooling to speed up production.

Fig. 6 shows the type of furniture fabricated and assembled by tooling installed by the firm of Woodwelding Italiana of Milan, Italy. By the use of a melamine urea-resin glue, the inlay can be spot tacked by using a small high frequency hand gun with ball point electrodes. The panel is then inserted into a hydraulic press where stray field electrodes imbedded in silicone complete final cure.

Example 7

Sales demand of modern furniture called for increased floor space to meet schedule. The unavailability of this needed space demanded a production flow, synchronized with proper equipment, to triple production in same floor space.

Figs. 7A, 7B, and 7C show Woodwelder and hand gun operators completing glue line cure, after removal from clamp where spot tacking locked the joint sufficiently for immediate transfer to assembly line. Repairing of damaged veneer was accomplished in the same operation.

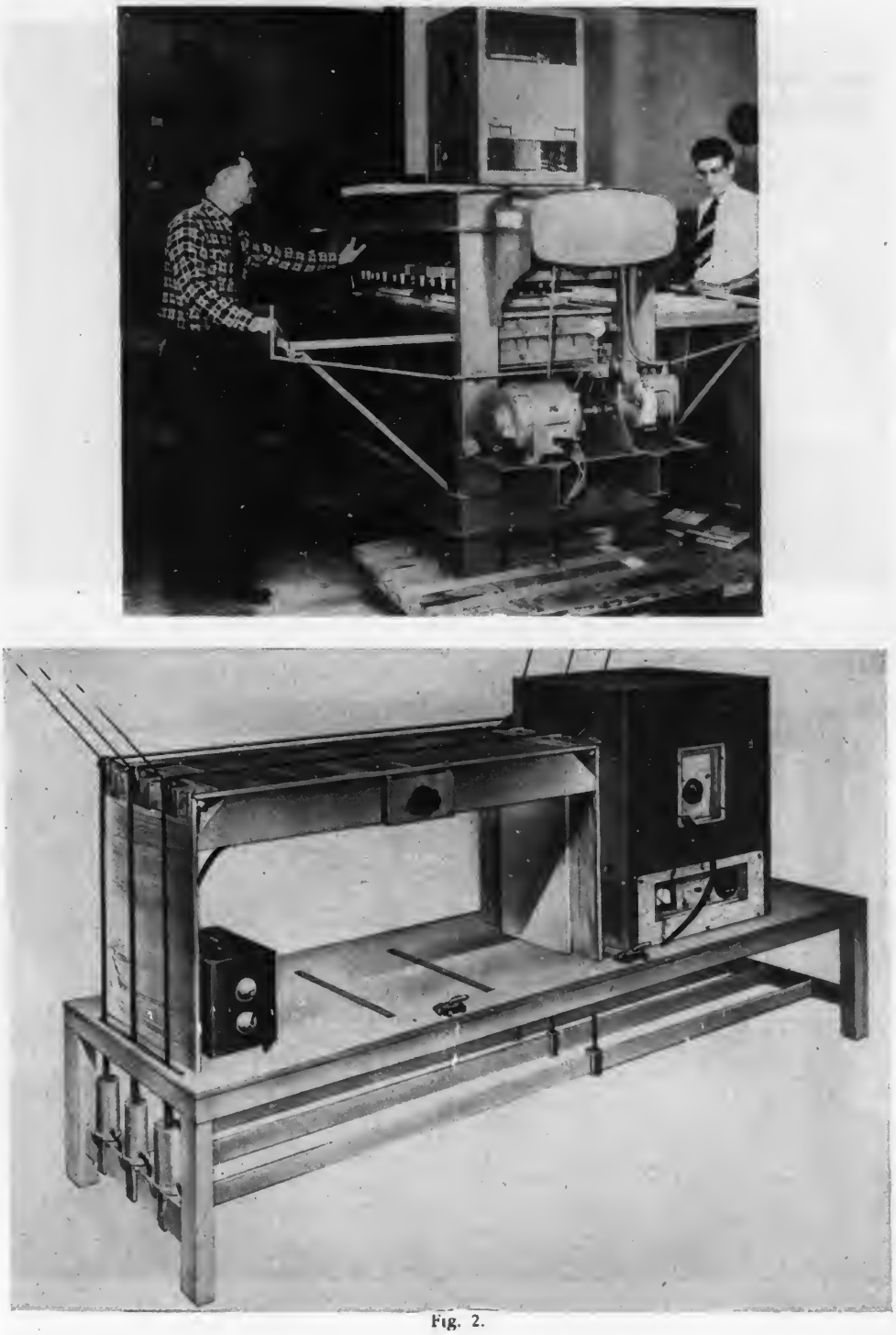

Fig. 2.

Fig. 3.

Fig. 4A.

Fig. 4B.

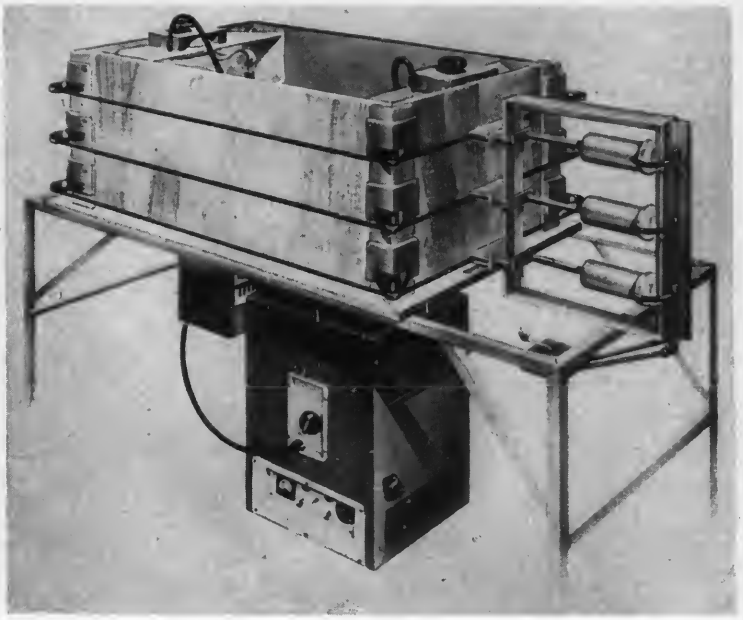

Fig. 4C.

Fig. 5.

Fig. 6.

Fig. 7A.

Fig. 7B.

Fig. 7C.

Fig. 8.

Example 8

The West Coast demand for modern furniture brought forth a complete change in manufacturing technique for this concern. Fig. 8 shows a piece of modern furniture prefabricated in sub-assembly for final assembly on the production line. The workman acquired skill in applying thin veneers and in edgebanding this furniture with hand gun used in an ironing movement. By using urea glues with high solids, contact pressure of glass shoe electrode smoothed the thin veneer on like wallpaper.

Conclusion

From the applications encountered in the furniture industry, it is evident that many are accomplished at a lower cost by methods other than high frequency installations. In other instances high frequency equipment versatile enough to do many fabrication jobs have created a difference between profit and loss.

TECHNICAL SESSION V

Wednesday, May 4, 1949, 9:00 A. M.

General Subject: Industrial Research and Development

Chairman: Carl H. Rishell, Director of Research, National Lumber Manufacturers Association, Washington, D. C. *(Southeast Regional Board Member, FPRS)*

Recorder: D. L. Haynes, Pack River Lumber Company, Sand Point, Idaho *(Chairman, Inland Empire Section, FPRS)*

Significance of Research to Industry

C. D. Dosker
Gamble Bros., Inc., Louisville, Kentucky

The forest products industries have made relatively little investment in research in the past, far less than has been invested by producers of products competitive with wood. The Forest Products Research Society can be a strong force in directing attention to developments resulting from research and research needs. The stimulation of research interest resulting from Society activity already is being felt, but it needs to be increased manyfold before the forest products industries are abreast of competitors and are in a position to compete not only in markets but in attracting to the industries the type of research talent needed to insure progress in developments.

THE subject assigned me is very general in its scope, and I will confine myself to the significance of research to the forest products industry.

We, who are assembled here, are members of the Forest Products Research Society. As scientific societies go, we are very young; as a matter of fact, we are an infant. The products, however, which this Society represents are ageless in their service to mankind.

The formation of the Forest Products Research Society is probably the most significant thing that has ever happened to this industry. The effect of this organization is bound to make itself felt not only on the economy of our industry but on the economy of our entire country. This Society is of tremendous importance to those who use the products of the forest in any form.

Research in forest products is divesting wood of the garments of tradition, and at last we are viewing it as a basic raw material capable of untold products that will benefit mankind.

This Society has greatly increased its membership since its organization. This is significant because it indicates a desire, or urge, if you choose, for increased knowledge about wood, a recognition of a need, a realization of the need to a scientific approach to many of our problems. We are, as a society, a group that is the outgrowth of the impact of World War II upon the wood-using industry. Many of us actively participated in some of the research work that was done on wood during the war.

Effect of Wars on Research

It is rather interesting to note that throughout history wars have had a tremendous influence upon scientific development. I believe that it is safe to say that organized research had its beginning in the United States in 1863. In that year, by act of Congress, the National Academy of Sciences was formed. Its purposes were to investigate and report upon scientific suggestions. Again in 1916, the National Research Council was formed by the National Academy of Sciences, broadening the scope of research. Developments during World War II continued this trend in research organization.

In every war man hours of effort are packed into research at a rate many times the rate of normal research in peacetime economy. It was so in World War II, and products and processes developed for war now are being converted into peacetime needs.

It has been stated, and I believe it is unquestionably true, that scientific knowledge advanced 20 years as a result of World War II. This is particularly true in the case of wood, and it is a very important thing to remember in connection with our industry. Some degree of the amount of this work can be obtained by simply looking through the "Forest Products Research Guide". This guide to research is published by the National Lumber Manufacturers Association in an effort to avoid research duplication, and to give source material. It is being kept strictly current. No laboratory or individual interested in research should be without this guide.

Present Limitations of Knowledge

We believe in wood. We do more than this; we believe in the future of wood as a raw material of rather unlimited possibilities. If we are honest, we will recognize the current limitations of our knowledge of wood as a raw

material and of the extreme importance of increasing this knowledge.

Much of this knowledge which we must acquire is basic. There is a tremendous job that must be done in the chemical field in qualitative and quantitative analysis of the various species of wood. Before we can combine wood with other materials, we must know what we are putting into this combination. We must know the answers to such interesting little problems as why the sap of the hard maple produces an edible syrup, when on the same land the adjacent oak tree produces an entirely different sap.

We must yet learn how to stabilize wood by a cheap commercial process. We do not yet know how to fireproof wood by any simple process. We still do not understand the complexities of photo-synthesis. We have yet much to learn about the potential possibilities of hybrid trees. We need complete knowledge of the chemistry of wood.

We all see and feel the need for more research in wood. What we have not yet discovered is the means of breaking down the lethargy that grips so many phases of the wood-using industry. As an industry, it has been in a deep sleep, drugged by the traditions of its ancient crafts. The masterpieces in wood are works performed by hand. Skill with the hand and not the head, practical knowledge that has not necessarily been correct, has guided this industry in its course throughout the centuries. We do it a certain way because grandpa did it that way. As an industry, we suffer from a disease I call "Grandpapyitis". As an industry, we must awaken to see those new horizons of products and processes that can flow from the research laboratory.

The industrial revolution started in this country shortly after the Civil War. With it came the machine age, the first of the mechanized woodworking tools, but really little progress has been made in the tools of our industry. New methods, new tools, new processes have been developed by those industries competing with wood in the consumer markets. We, the Rip Van Winkle of industry, are at last rubbing our eyes to take a look around us. This is significant.

What Is Research?

What is research? That is a good question, and to it there is no single simple answer. Research means many different things to different people. Let us recognize one very important fact, "people think as they are taught to think, and see what they are taught to see". We in the Forest Products Research Society must do something about this very important fact if we would seek to vitalize our industry.

I have always considered that research falls into two classes. The first is basic research, dealing in the fundamentals of wood as a raw material. It is a time-consuming and money-consuming job and can best be done by publicly financed laboratories or by institutional research. The second class of research is that which most vitally effects industry, and this is product research or product development.

These two types of research combine to form a tool of industrial management. Both types of research are essential, but it is the product research that carries the accomplishment of basic research to its final destiny—the products in the channels of commerce for better living.

Expenditures for Research

It is very difficult to determine the actual amount of money spent annually in research in our country. Those sources of information that I have checked indicate that the annual expenditure is from $180,000,000 to $250,000,000. There is a vast difference in the amount spent in various industries. In some industries as much as 2 cents out of every sales dollar goes back into research. Generally, it is nearer 1 cent. Those industries which are most progressive are also those which spend the most in research. It is rather interesting to note that the textile industry and the lumber industry are among the lowest in all major industries in the amount of money spent for research.

How pitifully small is the amount spent in forest products research in comparison to the value of its products. There is no clearing house within our industry by which the total amount that is invested in research can be determined. In the guessing contests that I have had with many individuals within our industry it seems agreed that at the present time less than $5,000,000 is being spent annually. It is

a guess, and it includes the funds expended by the United States Forest Service, which amount to around $1,250,000 a year.

In 1946, the last for which total figures are available, the estimated mill value of 36,500,000,000 feet of lumber produced was $1,400,000,000. This is lumber only and does not include veneer, plywood, pulpwood, railroad ties, and other products of the forest. The average mill value of the lumber is estimated at $40.00 per thousand feet. One percent of this would have been 40¢ per thousand feet; ½ of 1 percent would have amounted to more than $7,250,000, which the lumber industry should, in my opinion, have expended.

Some Needed Research

You might ask how a sum like this could have been wisely used? Let me just suggest a few problems requiring study:

What about low grade lumber? All phases of the lumber producing industry worry about it. Who is going to use this lumber and for what products? Is the low grade lumber problem a passing one? No, of course not, it is an ever increasing one. It will get worse, not better. A tremendous job in market research, product research, and process research is needed in this case.

What about hybrid trees for tree farms? Hybridization did a job for the corn grower.

What about fireproofing of construction lumber? Each year we see lumber legislated out of the construction fields. We spend money defensively fighting building code regulations. Why not try a new approach and develop a cheap, efficient method of producing a highly fire-retardant construction lumber? Where could you spend $7,000,000 in constructive research? That is not the problem. The problem is where to start first.

Even an uneducated farmer knows that you cannot continue to take from the soil without fertilizing. As all the forest products industry is farming, research is the tool by which the soil of markets can be fertilized and dollars spent in research is fertilizer.

Louis Pasteur once said, "Science is the soul of the prosperity of nations and the living source of progress". What is true of nations is also true of the industrial segments that comprise those nations. We are engaged in an industry that is notoriously non-technical. Most of its concepts are traditional.

Research Men

Let us examine for a moment the men who operate this "tool of management" that we call research. There are about 50,000 of them in our country, the scientists who work in 1,800 private and pubic laboratories. They are the men who keep the wheels of the more progressive industries turning at full speed. Far too few of them are engaged in our industry.

What is the power that makes a researcher tick? Well, I feel that the urge to research is an irresistible force motivating a curious mind to seek an unpredictable answer to a problem. The mental fuel upon which all research lives is "why". The antidote to excessive enthusiasm is "How do you know".

Knowledge alone does not qualify the scientist to engage in research. The qualification for research is knowledge "plus", and it is a great big "plus", and that "plus" is imagination. No new product or no new process can come from the laboratory until it has first been "imagineered" and then engineered. To do this requires a vast scientific knowledge of materials and processes and the imagination to combine them.

While many important discoveries are the result of pure chance, you cannot depend on chance to answer your problem. Hours of repetitive drudgery in experimentation, careful observation of minute details, and logical interpretation of results produce ultimate answers.

I have previously said that , "people think as they are taught to think, and see what they are taught to see". It is in this statement that I believe we can find the answer to the problem of research in the forest products industry. In it alone you can find the reason that accounts for the fact that many processes and products completed in the laboratory and ready for pilot plant operation continue to lie dormant. What is more discouraging to a researcher than the "stillbirth" of an idea. Why should many of the products and many of the processes still lie unused. The answer is obvious. The woodworker has never been told to think in terms of the benefit that accrue to him from research.

In his myopic vision he cannot see what is going on in those competitive industries which are stealing his markets.

A Change in Habit of Seeing and Thinking

The prime function of this Society within the next few years must be to change the thinking and the seeing habits of the men in the woodworking industry. They must, as an industry, be taught the significance of research. They must be shown the myriad of products and processes that lie on the frontiers ahead.

No matter to what extent money and time are spent in research, no beneficial results can accrue to any industry until that industry itself has the capacity to absorb and utilize this research. By capacity, I do not mean size of industry. I mean mental capacity within management. You cannot pour 5 gallons of products or processes into a 1-gallon can. You cannot pour 5 gallons of knowledge into a cranium that will only hold 1 gallon. We must attract to this industry more men with a scientific background if we are going to plant research on soil that will be productive. That, gentlemen, is the problem of the Forest Product Research Society. This Society is the stepping stone by which this industry can be supplied with containers adequate to hold these new products and processes.

It is not enough that management alone must have this capacity, it must extend to the plant level. The plant level is the "use" level, and understanding at this level is essential.

To me this matter of thinking and seeing, this matter of capacity, is the outstandingly significant thing in regard to research in the forest products industry.

Discussion

H. R. Sheppard, Jr. (Mellon Institute): As a researcher, I feel that one of the first projects or groups of projects that should be undertaken by forest products research groups should be concerned with obtaining the statistical information that is necessary to plan and evaluate properly their research work. This information is particularly necessary where product development programs are undertaken in which wood is used substantially as it is found naturally. Typical projects are concerned with fire-proofing, dimensional stabilization, rot and termite protection, and many others. As a rule this information can be published for the good of the industry without jeopardizing the individual's research work.

Mr. Dosker: I certainly agree with Mr. Sheppard that it is first important to obtain statistical information to plan and evaluate properly any research involving product development. You must determine whether the improved product can substantially expand current markets. Will the improved product help protect existing markets from loss to substitute materials? To do product development without knowing what you are trying to develop is a waste of time and effort.

Much information is already available if you knew where to look for it. The "Forest Products Research Guide", published by the National Lumber Manufacturers Association, can be very helpful in the determining of the availability of existing information. Nobody should engage in research in wood without an examination of existing reports of work already done.

L. R. van Allen (L. R. van Allen Company): "Old Grandpappyism," as Mr. Dosker puts it, is holding back the veneer manufacturing and wood products industry in general. An inventive concern can provide the results of 10 years of actual work on an important problem.

We believe a case in point is where the wood products producers have shucked off to the finishes manufacturers (paint and varnish and lacquer makers) the responsibility of giving uniform coloring and desired light coloring to ready-to-market products. The finishes manufacturers are glad to get that responsibility but weak in ability to handle it—but they get the money for trying it.

Our story is: *Many American grown woods can be brought to equal or excel in beauty of color any foreign grown wood.* Our contention is that correction of color to desired light shades is not necessarily a job for the finishing departments of store equipment builders, furniture makers and wood production of other sorts.

Sure! They'll tell you "we never did it before, so we *don't have* to do it now." Is that progress? Just because 50 million American

men wear hats modeled from toilet seats and have not tried to get their empty heads covered by any other style, only proves nobody wants to make a new move. Neither will a wooden-headed wood products man get out of the rut and be progressive. Well-proven processes are available for results very much worthwhile, but not for nothing. Anything worth something costs something.

A producer of small pieces, such as handles, etc., as well as veneer cutters, can put in simple additions to equipment and be in a position to offer something better than ever before. Better products bring more money. Light-color woods are salable. An inventive concern can provide the results of over 10 years of actual work on an important problem. But the concern wants to work under contract with mutual benefit and protection clauses. Grandpappy wouldn't sign it—but "Grandpappyism" isn't producing any results.

Mr. Dosker: Mr. van Allen is certainly correct when he states that the wood products manufacturers too frequently pass the responsibility for product improvement back to the suppliers of products used in processing.

The proper finishing of a product for market consumption is an important step in the manufacture of that product. Too many manufacturers using wood are inclined to tell the consumer that "here it is—take it" rather than point out the inherent qualities of the raw material that may add to its beauty and utility. Too many wood products manufacturers are too willing "to let George do it." George won't do it, so the product becomes static.

FOREST PRODUCTS RESEARCH SOCIETY

Research and Creative Business Management

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Creative business management can be as important in development and expansion of industries as research, and greatest progress is made when creative business management and research are closely integrated. The advantages of integrated wood-product-manufacturing operations are pointed out, and the possibility of establishing small wood-utilizing centers in localities having available timber resources and adjacent to good markets are explored. The forest products industries have been below other industries in participating in the business development, but there are indications that conditions are ripe for a rate of industrial development somewhat greater than that to be expected for industry as a whole.

EFFECTIVE industrial operation at the point of application requires creative thinking both in technical research and in business management. The conditions which make possible creative thinking in physical, chemical, and biological research have received substantial attention; it might be of interest to you if I examine the conditions under which business management is creative and the reasons for those conditions. I shall also make observations on the relation between technical research and management. The emphasis, of course, will be on the forest industries.

The historical trend of American industry has been notably creative. For the last 50 years production per capita has increased 2 percent per year compounded annually, after suitable adjustment for changes in the price level. Apparently the increase in productivity through most of the 19th century was of about the same order, although the statistical data are not complete enough for us to be sure of the rate. But production per employed worker per hour in terms of 1940 dollars was about 17.3 cents in 1850, 35.7 cents in 1900, and 74 cents in 1940, with an estimate of 89 cents in 1948.[1]

This is an outstanding achievement, the basis for the standard of living provided by our business structure for the American people. It is in part, but only in part, a matter of technology. It would be quite fruitless for us to argue whether technical development or business management is the principal factor; the result is accomplished only through a creative integration of both.

Business management as a partner in this process may vary all the way from a stodgy insistence on traditional methods to the chief source of significant developments. Both situations typically exist in each industry at the same time, although one or the other may be dominant. What are the reasons for the difference?

In the first place every management group consists of people trying to get things done *through people*. All of the persons concerned have established habits and patterns of thought and action. It is unrealistic to expect innovations to be put into practice until they have been accepted, logically and emotionally, by a substantial proportion of the group.

Second, the persons whose decisions count for most in any management group,—the presidents, general managers, and production managers, for instance,—are typically in the latter half of their business careers. The habits and patterns of thought of a man of 60 were typically established 30 or more years previously. This is one of the reasons for the normal time lag of half a generation or a full generation in adopting a broad new conception, such as sustained yield forestry.

Furthermore, traditional methods of operation have, by definition, worked—possibly not well, but they have worked. The burden of proof thus rests on those who propose an innovation to demonstrate that it will work better than the traditional method. As an essential

[1] J. Frederick Dewhurst and Associates, *America's Needs and Resources,* Twentieth Century Fund, 1947, p. 23.

Solomon Fabricant, *The Output of Manufacturing Industries, 1899–1937,* National Bureau of Economic Research, 1940.

Solomon Fabricant, Discussion Leader, *The Miracle of Productivity, Studies in Business Economics,* No. 9, National Industrial Conference Board, 1947, p. 6.

element of the innovation they should be prepared to bear the burden of proof.

All of you are abundantly familiar with the fact that new methods have bugs, often not seen at the beginning, which have to be ironed out. Getting them out is a further reason for the time lag of half a generation or more between the original conception and final use. This fact is particularly important from the business point of view because business management must of necessity appraise the risks involved before committing the funds and efforts of an enterprise to a new venture.

This is particularly true if the new venture has been conceived solely on a technical basis without a careful business analysis of markets and marketing organizations, production difficulties, investment in new facilities, availability of raw materials, and the margin between total cost and the net price to be realized.

In spite of all difficulties to be overcome, industry has been able to increase productivity for over a century, as already observed, at a compound interest rate of 2 percent. In the earlier years this depended on that small percentage of individuals who had the imagination and knowledge to conceive new methods or products, combined with the drive and business capacity to put them into effect; or it depended on a small group which cooperated to provide the requisite abilities. But both types of ability had to be applied.

A story about the early days of industrial research is intriguing. About 1910 Mr. Alanson Houghton, president of the Corning Glass Works, engaged a young glass chemist, Dr. Eugene Sullivan, and established him in a laboratory. Corning made a large proportion of the lantern globes used on American railroads. When a brakeman held a lantern out sideways to signal the engineer the flame hit one side of the glass while rain or snow hit the other side and the globe broke. Mr. Houghton said there must be some one type of glass best suited to resist these conditions and suggested Dr. Sullivan find out about it. Dr. Sullivan soon discovered that the coefficient of expansion was the critical factor and developed a glass with a low coefficient of expansion. The new lantern globes could take it, but more important, Pyrex glass was born, with applications all the way from cooking vessels to the 200-inch disc in the telescope on Mt. Palomar.

In this instance Mr. Houghton stated the problem, retained a highly competent person and provided the requisite facilities for his work. We have here a further instance of cooperation between technical and business thinking, which incidentally proved highly profitable.

It is true, with notably few exceptions, that enterprises which have developed industrial research departments over the last 40 years are leaders in their industries. Research departments properly integrated with industrial operations are an important, almost an essential means of maintaining a favorable competitive position.

By competitive position I mean the ability to produce and sell a better product at a lower cost than competitors. This is the source of profit and industrial strength, regardless of corporate size,—whether it be paper, electric motors, or lumber.

This matter of competitive position generates a driving force which is one of the main reasons for the dynamic quality of American industry. All of you have seen the process in operation, but its essential dynamic quality is not always entirely clear. Let us suppose that 15 firms compete in supplying kraft paper in northeastern markets. Several of them have costs which are about the same and yield a net return per ton which might be described as normal for the industry under existing cost and price conditions. One or more companies have difficulty in getting adequate supplies of pulpwood at a reasonable price, have obsolete mills and possibly managements unduly bound by tradition; their costs are just below the high prices of 1947 and 1948. At the other end of the scale are companies which have made judicious long-term arrangements for pulpwood, have new and well conceived mills and managements alert to take full advantage of new techniques and new management methods. Then prices decline. The high-cost mills are producing at a loss and are making every effort to better their position, but the very fact of high cost engenders financial weakness and makes the construction of new mills difficult. The middle group are also concerned with plans to improve their competitive position, lest

in the future they become marginal. The low cost firms are actively engaged in technical research and the development of management methods to meet the specifications of customers more exactly and to get a still more favorable cost position. The process is to a considerable extent cumulative, because the low cost firms have, by the very fact of low cost, greater financial strength for research, management and the construction of new facilities.

This striving for competitive position is an entirely normal, natural process, going on at dozens of points in the forest products industries, and at hundreds of points in American industry as a whole. It is a devil-take-the-hindmost process, rigorous, but on the whole highly effective as a dynamic force.

I am engaged at present on a case study of the cost of pulpwood in a series of companies with the objective of having specific figures on this component of paper cost. None of the cases are available yet, but one or more of them may be by the time of the meeting.

Modern management has to operate in industries where competitive position cannot be ignored. Successful managements have devised means for integrating planned industrial development in raw material acquisitions, getting out the production, quality control, cost control through standard costs and budgets, effective selling, research, finance and the problems of over-all management.

Time does not serve to describe these management methods in detail, but they have one common element; they call for able, well-trained men in charge at every stage of the operation and in all fields. The better managed a company is the greater is the opportunity which this competitive process provides for able men.

There is a further common element in that integration between business management and technical considerations is called for at every stage of operations. For instance, suppose a company is considering the installation of a new kraft paper machine in an existing mill. The decision whether to invest in a new paper machine and accessory equipment is a policy decision; it depends on a multitude of factors, the type and prospective cost of pulpwood, now and over a long term of years in the future, pulping capacity, stream pollution, the cost and availability of water and power, the availability of skilled labor and of competent management. The market must be appraised for the type of paper proposed to be made, including freight rates to the principal market areas, prospective price structures over a term of years and the relation of this machine to the capacity already in existence or likely to be built by competitors. Finally a decision must be made whether in view of the certainty of taxes and the uncertainty of everything else in business it is a wise exercise of fiduciary responsibility to invest funds belonging to a multitude of people in a very expensive new machine. It is in terms of business considerations that all of the technical factors are integrated in a final decision.

Even in a single component,—whether the machine is to be designed to operate at speeds over 1,500 feet,—the same process of integration can be observed. Technical problems in forming paper at such speeds, getting the water out within a reasonable length of wire, and wobble of rolls, might be overcome for a machine running permanently on a single specification, but if the sales department is going to ask for average runs of 5 hours the waste in change-over will use up any possible advantage from pushing the speed up to new limits.

As I appraise the situation in the forest products industries in comparison with other industries, I strongly suspect that the rate of industrial development in the past has been somewhat below that, for instance, in the metalworking industries. Possibly certain sections of the paper industry are an exception. The reasons for this relatively late development are by no means wholly clear. I should appreciate having your judgment on this point.

It would also appear that industrial development in the forest products industries in the next 20 years is likely to be particularly rapid. The research of the last 40 years in silviculture and of the last 25 years in utilization is likely to bear fruit. There is substantial evidence that conditions are ripe for rather notable changes in this industry, and I strongly suspect that they will be, on the whole, along the lines which students of forestry have been advocating for years.

A period of notable industrial development is by no means an unmixed blessing; it creates grave problems for those firms and individuals who do not participate in the change. But such a period also creates outstanding opportunities for alert and well-managed companies and for men of ability. The final beneficiary is the whole community, whether as producers or as consumers.

We might examine a few instances of developments already under way, or which are likely to appear in the future. One of these is in raw material, for it is a common characteristic of all forest products industries that they are dependent on the forests for raw material.

Most of you are familiar, I take it, with the sustained yield forestry and integrated utilization practiced by the Crossett Lumber Company in its operations in the shortleaf-loblolly pine area in southeastern Arkansas.[2] Apparently selective cutting and sustained yield were discussed as early as 1920; a definite policy putting these into effect was adopted in 1934. Here we have an instance of somewhat less than the half-generation time lag referred to above. Cutting is on an 8–10 year cycle with each tree appraised as to its growth possibilities over the next cycle before it is marked for cutting, or left. It was expected that costs of recovery would increase under selective cutting, but actually they declined.

Saw logs from these holdings of some 500,000 acres go to a notably well-planned sawmill. Limbed tops, thinnings, and bowed or defective logs of pine go to a 300-ton kraft mill, while hardwoods not of saw log quality go to a wood distillation plant.

This kind of arrangement not only provides for complete utilization but also facilitates a flexible determination of the most effective use for each type of material. In other operations one occasionally sees sapface yellow birch worth $180–$200 going through a chipper because there are no facilities for sawing it. I venture the assertion that in the heavy competition to be expected in the next 20 years a pulp mill not integrated with a sawmill will have difficulty in meeting competitive costs.

[2] S. V. Sihvonen, *Raw Material Supply for Integrated Wood Utilization · Crossett*, F. P. R. S. Proc., 3 (1949).

A person widely conversant with the southern shortleaf-loblolly pine area has told me that sustained yield methods proved in practice in the Crossett operations are now in use on 5,000,000 acres and that he expects adaptations and improvements on these methods to spread in 15 years over 50,000,000 acres. This is a normal development, in which an industrial process, proved in one instance, tends to spread, by virtue of the dynamics of competition. He also observed that with a general use of soundly conceived sustained yield forestry, the southern pine area can produce more lumber of a higher quality than it did from virgin stands.

I wonder if a New Englander, even though a Harvard man, may be permitted to take pride in the contribution of the Yale School of Forestry to the developments at Crossett?

In the hardwood field there are a number of very efficient operations, but I have not yet seen a fully integrated sustained yield operation. There would seem to be a place in the competitive structure for a series of small firms specially organized to deal effectively with the multiple products to be derived from mixed hardwood forests. I analyzed some phases of this problem in an article "Business Organization for Effective Use of Forest Products" in the Harvard Business Review for September, 1948.

The type of organization described therein as an hypothesis is one of about 100 persons operating in a radius of about 20 miles. It might own some land, but would operate primarily on stumpage contract, cutting being done in part by farmers and local contractors and in part by woods crews from the central organization. It is important that all cutting be on a long-term, sustained-yield basis under the supervision of competent foresters.

All material would be brought to a central mill for processing to meet the exact specifications of wood-using industries, or in some instances for sale to ultimate consumers. Provisions for effective quality control are essential. A forest recovery operation is similar to a meat-packing plant in that the material naturally produces multiple products. The cost of main products can be brought to the lowest feasible point only by an aggressive development of net recovery on joint products.

Quality control, direct cost reduction, and the utilization of joint products throw heavy weight on management. Even in an enterprise employing only 100 persons a management team of 8 to 10 men would seem to be essential to effective operation. It would be the function of the sales manager to know what could be sold where, and in just what form; of the production manager to meet specifications for the highest end use from the material available, and of the forester to see that raw materials came in at the lowest possible cost, from a type of cutting emphasizing the long-term interest of the stands. The function of the research director in the development of products and processes would be integrated with the entire operation. The controller should be thoroughly conversant with modern methods of cost control particularly in joint product industries. A management team of this nature would cost $60,000 to $75,000 a year. This is heavy for a small business, but possibly it is not too large relative to what the management can produce.

Can a group of enterprises of this sort establish a favorable competitive position in the structure of the industry? Research is under way to throw added light on this problem, including a study of the market for standard lumber parts and products and an examination of the cost and price structure under New England conditions from the stump to the finished product. Then a corresponding study of conversion costs should indicate available margins and prospects. If the results of the business research appear favorable, it will be highly useful if funds become available for industrial experimentation.

The prospect for small multiple-product recovery enterprises leads to a problem in purchasing policy. Many of the large industrial companies in other fields have developed a policy in purchasing materials and subcontracting parts in which attention is concentrated on long-term sources of high-grade materials from efficient, reliable producers, instead of on the lowest price for each order. Care is taken to see that prices are not driven below the point at which efficient suppliers can maintain industrial strength, and orders are timed with reliable firms so that their production schedules can be set up efficiently. There is rigorous competition among suppliers, but of a constructive sort; over a long term it shows more favorable results in cost and quality of material than an attempt to buy each order at the lowest possible price. Instances of constructive long-term arrangements with suppliers can be observed in the furniture industry, but I wonder if the practice is as widespread as it should be? It would be interesting to have additional opinions on this point from men purchasing lumber for furniture companies.

We have discussed competitive position so far on an individual firm basis, but there is another aspect which I shall refer to as "stump to consumer competition." It occurs in the paper and lumber industries, but we might draw illustrations from furniture manufacturing. It may be that Mississippi hardwood is milled in Memphis, manufactured into furniture in Grand Rapids, and sold through department stores in Washington and New York. There are certain advantages in this process, because each step is carried on by a specialist, and manufacturing is in large volume. But in North Carolina or New England there may be manufacturers who get their lumber from an integrated operation within 100 miles, manufacture in a small town, and sell their product within 200 miles. The competitive position is not simply that of the individual firms, but of whole chains of firms including retail distributors. Relative shifts of the balance of advantage will affect the whole structure of the industry. It is interesting to speculate whether a solution of the quality control and cost problems in dimension stock would enable the established furniture centers, such as Gardner, Jamestown and Grand Rapids, to obtain more of their material requirements as finished parts from producers in the growing area. I hope to obtain the judgment of some of our hosts at this meeting on this interregional competition.

May I depart for a moment from the affairs of the market place to point out how well adapted many parts of the forest products industries are to one of the newest developments in business,—that one of the principal factors in the success of an enterprise is in the living conditions of the people who work there. Let

us envisage a general location for an enterprise chosen with due regard for available forest areas, transportation, markets and possibly water power. But within the general location let us envisage a site, away from existing towns, chosen because it can be made a beautiful place to live. The community developed there should be complete—homes, stores, a church, inn, town hall and a mill architecturally and in function an integral part of the community. With local material available other plants probably would be required, possibly for furniture factories. In my own region such a community might be a classic New England village, with somewhat the spirit of Old Deerfield.

At first glance this conception may appear impractical, but if administered with the skill and insight it deserves, an enterprise so located would have a waiting list for every position available. It is quite possible that a business with these advantages could establish a highly favorable competitive position as a firm foundation for the whole community.

In summary, we may look forward with confidence to the forest products industries participating in the dynamic business development of American industry. In fact evidence indicates that conditions are ripe for a rate of industrial development somewhat greater than that to be expected for industry as a whole.

In order to accomplish this end it will probably be necessary to go somewhat further than we have gone so far in the integration of research and creative business management. Competition will be rugged. The dynamic drive for competitive position will produce some failures, but it will also create opportunities for those enterprises alert to foresee those opportunities.

FOREST PRODUCTS RESEARCH SOCIETY

Technical Development for the Small Company

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The experience of many companies is considered to have proven the necessity for development work in any industrial company. This paper is devoted primarily to a discussion of the fundamentals of organizing and administering the development function in a manufacturing business; the scope of the development work; its place in the company; the development program; and the cost and financing of this activity, especially as it applies to smaller companies.

IT IS not proposed to discuss at any length the question of whether or not a small company can justify research and development. The time seems to have passed when much additional effort should be necessary to prove that research and development expenditures, in the abstract, are not only justified but imperative. The cases offering proof are legion. If the study made by the National Association of Manufacturers in 1947 and published in booklet form under the title of "Trends in Industrial Research and Patent Practices" may be considered a satisfactory sampling of industry, 750 out of 983 companies, or 76 percent, replying to the NAM questionnaire stated that they carry on a research program. Considering the smaller companies with annual sales volume of 1 million dollars or less, out of 145 who reported having a research program and spending between three and four percent of annual dollar sales for research, 78, or 54 percent, reported having their own research facilities, and employing an average staff of four people. If research is not justified, there are a lot of companies, including many small ones, who are wasting a great deal of money.

To settle this question beyond any reasonable doubt, several typical comments on question 15 in the NAM questionnaire, namely, "What would be the effect on your competitive position if you discontinued research activities immediately?" are here quoted:

"Demonstrated success of research over past one-quarter of a century clearly indicates that a strong research program is essential to the maintenance of a strong competitive position in any industry."

"Continuing expansion of this small business has been possible only because of our research application."

"Research is insurance upon our future development."

"Impossible to discontinue research in our business."

"We consider research the most active stimulant to our business."

To those companies apparently constituting 25 percent of the total which have not integrated the research and development function into their operations, suffice it to say that a business which is not making specific technical progress is probably heading toward ultimate elimination.

Considering then that the research and development function is not only justified but imperative to the future of smaller companies as well as larger ones, specifically how shall it be organized and administered in order that the greatest returns may be assured.

Scope of the Development Work

A development project regardless of whether it deals with a market, a product, a process, a piece or group of equipment, or a raw material is of no value to the company, the community, or the employees until it has been commercialized, which means that operations have been established on a commercial scale with customers satisfied by virtue of attractive product value, and management and stockholders satisfied by virtue of attractive earnings. It is therefore necessary that the experimental work encompass three phases, generally referred to in sequence as laboratory, pilot plant, and production plant scale activities.

The experimental work starts in the laboratory toward the desired objective and a laboratory product is produced by a laboratory process through the use of laboratory or model apparatus. When a certain degree of perfection has been attained in the laboratory, and as soon as possible thereafter, a pilot plant is constructed and operated primarily for the purpose of test selling of the product to establish markets and product value, which is utility versus price; and secondarily to perfect plant design and crystallize manufacturing costs, which together with selling price determines the economics of the project. It is not unusual to rebuild and enlarge the pilot plant several times before reliable answers to these questions are at hand.

If the project is sound, the time arrives sooner or later for the preparation of a Capital Proposal for the construction of a production plant for submission to management for the appropriation of the necessary funds. This proposal covers all the questions which must be answered before money can be invested in a business, the principal ones being:

The nature of the product and the markets for it.

The quality of the product relative to the requirements of its use, or in other words the utility of it to the customer.

The price of the product relative to its utility, and hence the value which the customer receives as compared with competition.

The unit operations making up the overall process.

The selection of equipment.

The general arrangement of the equipment.

The capital cost estimate.

The direct manufacturing cost estimate.

The gross profit estimate.

The working capital estimate.

The net income estimate.

The time necessary to repay the capital investment.

If the proposal is favorably acted upon by management, it then becomes an engineering job to design and construct the plant, which is usually not a development function. However, when the plant is ready to operate, the job of making it produce according to quality, cost, and production rate forecasts is a development responsibility so far as the technical aspects are concerned, and the development job is not complete until a satisfactory plant performance has been achieved.

It is clear from the foregoing that as a project progresses to full production stage, the money to be appropriated and the staff time to be allocated increase by leaps and bounds. The laboratory stage expense is small, the pilot plant expense is substantial, the production plant expenditures may run well into five, six, or seven figures and take much of the time of the whole department. The problems to be solved likewise increase rapidly in complexity, and the production plant when built must measure up to the three standard business objectives, namely continuous and profitable employment for the workmen, a profitable investment for the stockholders, and a product of attractive value for the consumer.

Centralized responsibility and authority in development matters are as important as in any of the other company functions or perhaps even more so. To transfer or divide responsibility at the end of the laboratory stage or at the end of the pilot plant stage is to jeopardize the success of the project and to place unnecessary hurdles in the way of commercialization, without which there is no justification for having started the project in the first place. With the responsibility centered in a development department for the commercial completion of the project, that department is solely responsible for progress or the lack of it.

This matter of the scope of the work is the first basic consideration, for upon this depend the organization of the department, its program, budget, and place in the company.

Granted that the inclusion of all three stages of laboratory, pilot plant, and production in one department is sound, it is clear that this scope is beyond that usually designated as research. The term development as used in this paper designates this three-stage sequence and includes research as dealing primarily with the laboratory stage.

The Place of Development in the Company Organization

Before development as a company activity was generally recognized, there were two primary functions, production and sales. The business of production is to manufacture a product of standard quality at a standard cost for delivery at a specified time. The business of sales is to sell a product of standard quality at an agreed upon price for delivery at a specified time. Both carried on experimental work from time to time, production usually being most interested in decreasing costs, sales most interested in expanding markets. Both required technical service, production as a check on and help to plant performance, sales as assistance to customers.

As long range planning came more into vogue, it became evident that long range objectives could not be reached by either production or sales working independently. Furthermore, diversification of markets, almost universally found as a company objective, involved projects quite outside the experience and knowledge of either of the two departments. Consequently it came to be recognized that the department to be responsible for the major developments of the company, should be independent of either sales or production and on a par with them, thereby providing a triumvirate, with production and sales responsible for the success of the business as currently established and development responsible for changes and additions to the business as planned for the future.

A modern business organization resembles a three-legged stool and no one of these legs, production, sales or development, is self-sufficient. The commercialization of any development is a joint accomplishment. It makes little difference how brilliant the development work may have been; if management does not provide the dollars, production the manufacturing skill, and sales their strong merchandising ability, the whole project will in all probability die on the vine. The team must function to reach the commercial goal.

Service functions involving technology are not to be confused with development and belong in the other two departments, as for example that commonly called plant control in production and technical service in sales. It is also quite impractical and unjustified to discourage the execution of some development work by others in the company than the development department, since every competent production or sales manager is always considering how improvements may be made. These matters may best be controlled by the proper financial budgets, since the cost of such work must inevitably appear either in cost of manufacture or cost of selling and these costs will not generally be permitted to get much out of line. Except for these deviations ,the development expense of the company is all consolidated in the development department, its magnitude is known at all times and its control via the usual budget system is relatively simple.

The Development Program

The careful planning of development work is imperative. Even when this is as well done as possible by a group of competent executives, the quality of the job in retrospect on occasion does not merit any blue ribbons.

First many questions arise to which tentative answers for guidance must be given by management. Typical questions are:

- Are the markets being presently supplied attractive enough to be continued over a long period of time?
- Do present products give satisfactory value to the customer or is the need for improvement urgent?
- Are present markets of such breadth and volume that new products are justified to strengthen the company position?
- Do present products lend themselves to reaching other valuable markets?
- Is the business balanced between durable and consumer goods?
- Is the business balanced between industrial and dealer outlets?
- Is it advantageous to remanufacture to get the products closer to the consumer?
- Is the business seriously seasonal?

From consideration of these matters, there crystallizes certain company objectives which constitute the navigational aids, so to speak, for the development work over a period of years. Thus one will know, at least in general, whether the major company problems lie in markets, in the product, in the processes, in the equipment,

in the raw materials, in prices or in costs, and so on. Knowing this, it is possible to concentrate the development program on the most important objectives to the practical exclusion of other avenues of work even though superficially more attractive.

In discussing the establishment and nature of the development program, the most important factor at all times and regardless of details is the consumer of the product which the company manufactures. The consumer is the originator of the order file, and without an order file any company ceases to exist. Whether it may be pleasant or unpleasant, everyone in industry works for and takes his orders from the customers of his company. Every use to which a product is put has a list of ideal requirements as long as one's arm. There is no product in existence that comes anywhere near meeting all the requirements of use. There is no perfect product. The utility of a product for a specific use is the degree to which it satisfies these requirements. Price of the product and utility of it go hand in hand and taken together constitute the value of the product. The lower the price for a given utility the greater the value. The greater the utility for a given price the greater the value. The product of the greatest value will be the one favored by the customer and consumer.

These attributes of product utility and value are very fundamental to all development work, so basic in fact as to lead to a very useful classification of fields of development work as related to company objectives previously discussed. These are:

1. *Holding present markets with present products.* This is the first responsibility to those who work for the company, who own the company, who buy from the company, who sell to the company, and who as a community depend upon the company. Present products are always susceptible to increase in value to the consumer. The work may involve any avenue of greater compliance with use requirements or of decreased cost of manufacture. The extent to which this work is made long range, however, depends upon company objectives relative to present markets and present products. Developing or acquiring conversion plants to approach closer to the ultimate consumer falls in this field.
2. *Increasing present markets through new products.* If long range studies indicate that present markets are well worth protecting but new products can be visualized which may be expected to reach values unattainable by present products, major developments can well be initiated in this field.
3. *Procuring new markets for present products.* Market diversification is often an important company objective either to divide sales between industrial and consumer markets, to level out seasonal demands or to insure against too great fluctuation in volume with the changing business cycle. There is no more ideal means of securing diversification than by developing new markets for present products. This field of work should always be explored thoroughly.
4. *Procuring new markets through new products.* This field is without limitation; hence, activities in this category must be scrutinized carefully so that they do not go too far afield. Market diversification sometimes cannot be obtained in any other way, but in so doing the integration of the new processes and raw materials into present practice should if possible be achieved. Of especial interest is the case where the company owns or controls its principal raw materials. If increased or improved utilization of raw material can be combined with product and market diversification, a prize winning combination results. The utilization of by-products falls in this category.

The key element in the administration of development is the annual program. Upon the wisdom and foresight of the executives charged with the responsibility for this planning depend not only the performance of the development department but the future of the company. The program itself consists of a number of individual items arranged in priority order, each item carrying its own objective, justification and plan of attack. Usually the first list of

items worked out contains many more than can be efficiently handled during a given time. The task is to weigh many factors for each item and select the winners before the contest begins. Some of the factors to be considered are:

- Assuming the development objective to be completely reached, will commercialization be carried forward and capital funds appropriated when the time to do so arrives? Reports reposing in the files do not help the customers, the stockholders, or the employees.
- What period of time to commercialization is involved? The longer the time the less attractive the item.
- What are the chances for success? Are there several avenues of attack or only one? Is inventive genius involved or the following of well-known procedures? Is the problem to be solved an old one on which many have worked but none succeeded, or is a new field being entered? A few "sure fire" items on the program are very desirable.
- Are special facilities or highly trained specialists required?
- Does the item integrate into present operations?
- Does the item diversify markets and if so is the probable sales volume large or small?
- If the item falls in a competitive field, wherein will the advantages lie and to what extent as compared with competition?
- Does the item diversify the program? A well diversified program is an important factor of safety.

The program, once established by competent executive action, becomes the development bible for one year and is not subject to change except through unusual circumstances and by executive approval. There is nothing more disastrous to development progress than frequent major changes in the items of the program or their objectives. It is the responsibility of the development department to reach the objectives set forth which the best minds in the company have agreed will benefit the company most, and nothing outside these objectives is of any great consequence for the time being. Strange as it may seem and obvious as this fundamental may appear, it is one of the most difficult assignments of the development chief to see that this rule is not seriously violated.

A corrolary to the foregoing is the importance of continuity of effort from year to year, from annual program to annual program. A well-known rule of thumb is that it takes seven years on the average to reach the stage of profitable commercialization. Some of the same projects then must appear on the program year after year and to keep them there is another difficult task. It is a strange commentary on human nature, but nevertheless very true, that enthusiasm for a given project is at a peak when the first reasonably good laboratory results are obtained. Then as use requirements become better known, deficiencies are clarified, both capital and manufacturing costs are visualized, interest is not so keen. When the pilot plant begins to deliver the product to the consumer and the extent of one's lack of knowledge becomes evident, the backers of the project are often conspicuous by their absence. So, many developments have a stormy career over a long period of time and final success involves a great deal of courage, patience, persistence and optimism not only on the part of the development men involved but of management as well.

The Cost and Financing of Development Work

The discussion up to this point is applicable more or less regardless of the size of the company. Matters of cost and financing introduce the factor of company size and raise the question of whether or not a so-called small company can afford a development department strictly on the basis of availability of funds.

First, since development is an overall or independent company function dealing with projects involving all elements of the business, the cost of development is a top management charge to be paid out of earnings. It is insurance for the future as a great executive once said, to tell you what to do when you can no longer do what you are now doing. Its cost is then to be returned in the future.

Next, the cost of development is made up of both capital expenditures and operating expense. When a development department is organized, there must be physical facilities with which to work, which is of course capital. But

more important, as the work proceeds, pilot plants, model machines, or plant changes and additions as alternatives to pilot plants must be made in order that the work progress toward commercialization and these are capital expenditures. Finally, if a production plant is to be built, the capital funds must be made available, or the final pay off on everything which has gone before will not be accomplished. This final production plant is not a part of development cost, standing on its own feet for justification, but such investments must be visualized and recognized as resulting from the development work and as being the most essential step in the whole chain of events in realizing the returns expected from the money previously invested in the development programs.

Work on laboratory scale is relatively inexpensive. Pilot plant scale operations involve substantial appropriations for both capital and expense. Since a pilot plant is unlikely to be operated more than four years, depreciation rates are very high. Sale of goods helps defray the cost of operation after the shake-down period, but a profitable pilot plant operation is rare indeed. Capital cost of a new production plant generally exceeds substantially any previous appropriations in connection with the project. If capital money is likely to be in short supply, the program items can be so chosen as to minimize this requirement.

One of the many objectives of centralizing development work in a so recognized department is the control it gives over the expense of experimental work. Hence, all elements of cost should be included in the development budget so that it pays its way and is not forced to ask other departments to lend assistance without being properly reimbursed. For example it is often desirable and justifiable to carry on experimentation in a production plant rather than to construct special experimental facilities. These are sometimes referred to as plant trials or mill trials. The extra cost of such trials is not a part of manufacturing cost and expense thus accrued must be paid by the development department.

The research or development budget is ordinarily expressed as a percentage of net dollar sales in the same manner as other items of the financial operating statement. The magnitude of this budget can be anything from that necessary for the efficient functioning of one high-grade technologist to the maximum diversion of net earnings which the company can afford. It is most practical to set the budget up on the basis of funds which can reasonably be appropriated and then generally fit the program to the funds, rather than by reverse procedure. It is not practical to set up the program and estimate cost by items to arrive at a total budget, because no one can foretell the difficulties or lack of them which will be encountered in the case of any given item. It is of course entirely proper for management to put a ceiling on expenditures under any one item so that the results and justification for further work will be carefully reviewed before further expenditures are incurred.

Many companies have been and are started and owned by men who themselves did the original development work and consequently in the early stages of company growth, these men continue to be the development department themselves. In the booklet of the NAM previously referred to, 138 companies in the range of $100,000 to $1,000,000 annual sales reported having a research program and spending an average of 3.8 percent of annual sales thereon.

The question which is now of interest is, at what point in the growth of a company as measured by dollar sales volume is it practical to set up a regularly constituted development department. This is not to say to begin development work, but to recognize it as a full-fledged department. The minimum with respect to development staff would appear to be one high-grade technologist or engineer with several assistants as represented by an annual gross salary pay roll of perhaps $16,000. Other direct expense may be about 15 percent and indirect expense 25 percent, or a total of 40 percent of the pay roll or $6,000 of other expense annually. Outside professional services, both technical and legal, are a necessity. It is only wise to seek a specialist when his services are required and few if any development staffs can afford to be self contained. $6,000 is allowed for this expense. Mill experimentation or one operating pilot plant may take another $11,000, making a total development budget of $39,000.

It is clear again from the NAM data that the ratio of research expenditures to dollar sales is

greater for the smaller companies and varies greatly from industry to industry, the 1946 average actual being 1.87 percent. It seems reasonable to select 3 percent as the ratio for the hypothetical company involved in these estimates, which places annual dollar sales at $1,300,000.

Net income of many companies falls in the range of 10 to 15 percent of dollar sales. Using 15 percent for the example herein, net earnings would be $195,000, of which $39,000, or 20 percent, would be allocated to development. Dividends of large companies are currently averaging about 50 percent of earnings, but it is unlikely that smaller companies would pay out that much preferring to plow the funds back into the business. If 30 percent be allocated to dividends, then 50 percent or almost $100,000 is available for capital expenditures, increased working capital, and special reserves.

If the foregoing assumptions are reasonable, it appears that a regularly constituted development function may be incorporated in the business when annual dollar sales exceed $1,000,000. Certain it is that this function is as necessary in a small company as a large one and the earlier it can be independently set up, the more will rapid sound growth of the company result. There are many other phases of the development function which it would be interesting to discuss, the functional type of organization involving team play, the personnel requirements, the methods of administration, public relations policies, and so on, but time is not available.

In conclusion, development is that company activity which brings about in a planned and rational manner the major changes and additions to the company business to maintain and improve its position. Its work carries through from inception in the laboratory to proven commercialization in the plant. It constitutes a major independent department. Its planning is made specific through a formal annual program of carefully diversified, stable items with clear objectives, of high probability of success and of ultimate commercialization.

No company can afford long to remain uninsured relative to its future, and those of the smaller companies who do not already enjoy this insurance need have no fear of the expense of establishing and carrying on the development function provided the individual company situation is intelligently analyzed and funds are budgeted within the projected resources of the enterprise.

Discussion

Roy M. Carter (North Carolina State College): The technical development program cited by Mr. Heritage is the most comprehensive, complete analysis that has been made for the wood industry. I commend this for further study by all managers and technicians in the wood working industry.

Investigations from the laboratory through the pilot plant stage and ultimately getting into production are essential steps in the complete development program. To finance such a three stage program, Mr. Heritage estimates that a gross sales volume of about a million dollars is required. Since wood-working businesses as a whole are small industries there are many plants with gross sales below a million dollars. These small concerns also need a development program to keep abreast of improvements that can be made in their operations.

If we classified the wood industries on the basis of gross sales we would find they would form a pyramid with a tremendous number of small industries at the base tapering to a point with a few large concerns at the peak. On the basis of the pyramid the number of plants that should engage in a technical development program would increase if we included those companies with less than a million dollar gross sales as cited by Mr. Heritage. Assuming that there is a need for research information in small wood industries as well as large companies, I believe there are some steps that small companies can take. Mr. Heritage points out that a developmental program consists of three stages: first, the laboratory investigations, second, the pilot plant scale, and third, production processes. As a general rule there is more laboratory and fundamental research available to the wood working industry than is applied. There are also many concerns working on a pilot plant scale. After completing the pilot plant stage much of the development never goes into production due to economic conditions or a reluctance to change, which is common in most industries. It therefore is possible for

many small plants to by-pass, temporarily, the laboratory and pilot plant stage of their development program. The small industry then could consider ways and means of putting the information that is available into production. The number of plants who could do this would exceed the number who establish a complete developmental laboratory and staff. Many small plants are under the impression that they are adopting the results of research as fast as they can. Nevertheless I believe many more technicians could be employed by the wood industries to "sift the wheat from the chaff" in a conscientiously planned manner.

The Forest Utilization Service men at the several Forest Service Experiment Stations, who are field men for the Forest Products Laboratory, have found that the small industries are extremely interested in ways and means of applying research information in their particular plants. The bulk of the requests for assistance come from the small industry that cannot afford to hire consulting engineers or have a complete development program in their own plant. To begin with they think they cannot afford a technologist but sooner or later they recognize that it would be desirable to have a man who could analyze the available information. With normal growth of the industry, this realization is the first step the small industry can take to direct its efforts into a technical development program.

W. A. Hosmer (Harvard University): Mr. Heritage has discussed with great thoroughness the functions involved in research and development, together with the organization required to get these functions performed. But one gets the impression he is dealing with a scale of operations adapted to a large company. The problem is of course important in a large company and one can get a great deal of information about the requisite functions from such a clear description.

The problem is basically different in a small or medium-sized company. The percentage which research and development expense may reasonably bear to sales is limited, and this establishes a definite limitation on expenditures and on organization. Mr. Dosker has very properly emphasized the importance of research regardless of size, and it would be unfortunate if the view prevailed that research and development could only be undertaken by large companies.

One of the characteristics of small enterprises is that executives have to perform more than one function. This is probably applicable in the research and development field, but it is important that one or more executives have this as a definite part of their duties. Probably most of the basic research for small and medium-sized companies will be done as it has been, by the Forest Products Laboratory, our several colleges of forestry, and other institutions. A great deal can be accomplished in small companies if their research and development activities are kept in close and systematic association with these agencies. Under these circumstances the effectiveness of a small research organization can be greatly expanded.

C. A. Risbell (National Lumber Manufacturers Association): Mr. Heritage has clearly expressed the thoughts of most of us who are responsible for managing research. It seems strange that it is necessary to emphasize the fact that a complete research project is of no value unless it is put into practical use when such a statement is axiomatic. No one in his right mind would contradict this statement, but on the other hand it is surprising to learn of the large number of management personnel who set up research projects without thought as to the cost for pilot plant work and even less consideration as to the cost of putting the results of the research into practical production.

There is a logical reason why this should be so, even though it is hard to understand. Successful business people have become successful only because they are capable of undertaking calculated risks. When they are dealing with familiar subjects, they are on safe ground, but when dealing with unfamiliar subjects then the risks are no longer calculated or susceptible for analysis by them.

Research is an enticing word. To the uninitiated it probably brings up visions of a chemist performing sleight-of-hand tricks with a test tube, but, as Mr. Heritage states, the work in the test tube stage is very cheap in comparison with the construction of production plants. Unfortunately, the visions of uninformed management do not extend further

than the test tube stage. I presume the average person does not realize that the bulk of the two billion dollars used in producing the first atomic bombs did not go into test tube research but went into the construction of large production plants. If this thought can be brought home to the average businessman, then the orderly development of research can proceed. Really this is the meat of Mr. Heritage's talk.

Mr. Heritage also said that once the development of a research program is set there should be no major change of objective except because of very unusual circumstances and yet this fundamental rule is very frequently violated. I know of one instance where the principal objective of quite a large research program was changed after 90 percent of the money had been expended on the objective as originally set forth. Such compulsory changes of objective usually result in thorough confusion of the technical staff but more important the entire program is in danger of being discredited. Management is interested only in results. It has a short memory when lack of results can be attributed directly to management.

A statement that could well be read and reread by people who have put their money into research development is the rule of thumb guide that it takes seven years on the average to reach the stage of profitable commercialization after the research project has gone through the test tube stage, perhaps even the pilot plant stage. The management of small concerns is usually impatient. Research or development is all too frequently viewed as being in the same category as high speed production. It is for this reason that Mr. Heritage stated: "A few 'sure fire' items on the program are a necessity." How true this statement is no one will ever know until he attempts to manage group research.

I would like to emphasize Mr. Heritage's clear-cut statement with respect to the cost of maintaining a minimum development staff. I believe that the figures which he has quoted are very accurate. Unfortunately, from the comments which have been made from the floor, it appears that many of you think that Mr. Heritage is trying to discourage small companies in undertaking research and product development. I believe it quite evident that this thought was furthest from his mind. He does say that probably the minimum cost for an adequate development staff is approximately $39,000 per year. This is only too true, but Mr. Heritage did say that no company, no matter how small, can afford to ignore research and development. I presume by this he means that someone in management should be responsible for undertaking new developments. If the company is not large enough to maintain its own separate development staff, then management through other research agencies not owned by the company can develop in an orderly way until such time as a development staff can be afforded. I certainly agree with Mr. Heritage that as soon as possible any concern should have its own development staff but we should also remember that he has suggested that this development staff can seldom be large enough or sufficiently diversified to encompass all the arts and skills that are required in modern research. In fact, in his minimum $39,000 budget he has included an item of $6,000 for outside technical assistance.

Mr. Heritage: It is regretted that apparently the impression was gained that a sales volume of a million dollars is required for the establishment of a development program. Certainly this is not the case. Such a *program* can and should be established by every company no matter how small. What was said is, "a *regularly constituted* development function may be incorporated in the business when annual dollar sales exceed $1,000,000". This was intended to mean an independent department with proper quarters, facilities and operating budget. If a greater proportion than 20 percent of net income, in the example given, be allocated to Development, then the necessary sales volume drops accordingly. When the company is too small to incorporate development as a regularly constituted function, then the development program must be executed by staff members with multiple responsibilities. Usually in these cases, however, development costs are buried in other costs so adequate knowledge is not available of what developments are going on and how much is being spent.

There is no use kidding anyone about the expense of development work. Any company

no matter how small which does not do its own Development planning or skips pilot plant or mill trial stage or does not seek the guidance of recognized professional experts when needed is headed for trouble. As stated, one engineer can constitute a Development Department if provision for the expense contingent upon his work is made. Very few companies are so small they cannot afford consulting services and a real development program even though it consists of but one project. But the planning for a specific company and the execution of the plan can seldom be delegated to outside agencies.

Wood Award Presentation

Herbert A. Vance

Publisher, Wood Magazine, Chicago, Ill.

Mr. President, fellow members, distinguished guests. It is a pleasure to be present at the Third National Meeting of the Forest Products Research Society, and note the growth and progress that has taken place since this group was founded three short years ago. My task is doubly pleasant, as I am presently to announce the recipient of the 1949 *Wood Award*.

Those of you who attended the meeting last year in Chicago, will recall that each year *Wood* magazine presents $500 and a certificate of recognition to the student in an American school or college, who submits the best technical paper on research that is considered by the judges as the outstanding college contribution to the wood industry. I want to thank the following judges personally for the excellent job that they did, in addition to their regular activities, in the midst of as busy a Spring as we have had since the end of the war:

Dr. Edward Locke—Chemical Engineer, U. S. Forest Service, and 1st Vice President of FPRS.

Mr. Robert Pauley—Manager, Development Department, Weyerhaeuser Timber Company, and Regional Board member for the Pacific Northwest, FPRS.

Mr. James Hamilton—Technical Service Director, Perkins Glue Company and Second Vice-President of FPRS.

Mr. Fred Gottschalk—Technical Director, American Lumber and Treating Company, and Past President of FPRS.

These judges, plus members of *Wood's* staff, were responsible for selecting the best report from papers received from all over the country. It was their considered opinion that this year's crop of aspirants presented material that was of much higher caliber than that received for judging last year—making the decision doubly difficult.

This year's winner is *John Ledyard Hill,* a native of Milan, Minnesota, who was graduated from Colorado State College in 1942 with a Bachelor of Science in forestry and who then enlisted in the United States Army. Following three and one-half years in the Field Artillery, with 20 months in the European Theater of Operations, First Lieutenant Hill returned to civilian life and entered the Yale School of Forestry after the war. He received his Master of Forestry Degree in 1947 and has been working since that time toward the completion of work leading to the degree of Doctor of Forestry.

Mr. Hill has developed an improved method for selecting Balsa wood of high tensile strength properties and incorporated the results of his special research project into the paper which won for him this year's *Wood Award*.

At this time, when wood products of all natures and descriptions are receiving the brunt of competition from every type of material imaginable, and some almost beyond comprehension, it is encouraging to note that a graduate student can develop a method to classify a species better and thereby preserve an important market. We can not dwell enough on the importance of members of the wood industry aiding in every way possible the research activities of those interested in preserving and extending our markets. It is only through organizations such as this Society, the Forest Products Laboratory, private research organizations, and association groups, that we can all work together to develop and protect the markets for forest products—nature's only replaceable raw material.

Therefore, it gives me great pleasure to introduce to you, *Mr. John Ledyard Hill.*

Mr. Hill, as Publisher of *Wood* Magazine, may I present you with this certificate of merit and a check for $500, which I sincerely hope will encourage you to continue with your efforts in the line of forest products research. As this year's winner, you have given next year's *Wood Award* aspirants a high mark at which to aim. My heartiest congratulations to you, with best wishes for continued success.

Thank you.

FOREST PRODUCTS RESEARCH SOCIETY

Wood Award Thesis

A Simple Method For Selecting Balsa (*Ochroma Lagopus* Sw.) of High Tensile Strength

John Ledyard Hill

School of Forestry, Yale University, New Haven, Connecticut

Introduction

WOOD has certain inherent physical properties that make it particularly valuable as a structural material. Significant among these is a high strength-weight ratio parallel to the grain, a property which is largely responsible for its advantages over other materials equivalent in weight. Wood, therefore, is especially adaptable to aircraft construction where weight is a primary consideration. Balsa wood is exceptionally qualified for this use in that it has a remarkably low specific gravity (0.05–0.24) *(2)* without any appreciable reduction in the strength-weight ratio parallel to the grain.

Because balsa combines the two properties mentioned above (i.e., low specific gravity and high strength parallel to the grain), it is rather extensively used as a core material in stressed-skin panels for floors and for fuselage, wing, and control coverings of aircraft. In this type of construction, balsa is often prepared in the form of cross-sectional wafers which are glued to each other and then to the face plies so that the grain of the wood runs in a plane normal to the faces. Such a grain orientation of the core material employs to advantage the relatively high resistance to shear across the grain, characteristic of other woods as well as balsa. The properties of balsa are thus utilized to permit the development of a very stiff yet lightweight panel with a core sufficient in strength not only to preclude shear failures within the core, but also to resist stresses tending to separate the facing materials and to crush the panel. This balsa-core panel appears to be particularly adaptable for use as a covering for the ultra-high-speed aircraft being developed today.

To be successfully used for such core material, however, balsa wood must be of uniformly high tensile strength along the grain, a requirement which suppliers have had great difficulty in satisfying due to the extreme natural variability even within a single stick. In order to protect itself, the aircraft industry devised a somewhat arbitrary method for identifying a type of poor-quality balsa known commercially as "corcho." The method consisted of drawing a blunt scribe across the end grain; if the fiber picked up in chunks ahead of the scribe, the stick was discarded. Such material was presumed to contain so-called corcho and to be weak in tension along the grain. Although this method probably indicates the presence of low-strength balsa in a stick, it seems likely that unreasonable amounts of balsa are being rejected. Unfortunately, as a result of this situation, balsa is in danger of losing a market for which it is uniquely qualified.

It is therefore the purpose of this study to devise a simple method, the application of which will not only identify high-strength balsa but will also accurately define its limits within a stick.

Experimental work leading to the establishment of a method of differentiation proceeded as follows:

1) Exclusion of all balsa material containing visible compression failures, decay, or other defects which are known to influence tensile strength.

2) Study of the remaining defect-free material to develop a method of differentiating high-strength and low-strength wood.

3) Establishment of proof of the validity of the method developed under (2) by testing and subsequent statistical analysis of the data.

4) Confirmation of the significance of the method by demonstrating that it separates balsa into distinct strength classes even though these classes may be similar in specific gravity, and by establishing an anatomical explanation for this behavior.

Material

The balsa used in this study was obtained from "AA" grade (Aircraft) stock, all of which had been rejected by an aircraft concern because it failed to pass the scribe test. Nothing is known regarding the growth, cutting and handling of the material before it was received at the Yale School of Forestry. It was apparent, however, that the wood had been kiln dried.

Description of Species

The information presented here will give some idea of the problems of quality control of balsa, as well as explain some of the extreme variability of this species.

Balsa is a very fast-growing tree found throughout tropical America. Although many species have been described, Record and Hess *(4)* and Pierce *(3)* indicate that *Ochroma Lagopus* Sw. is the only justifiable one.

According to Record and Hess, "given ample room on rich, well-drained soil at low elevations, the trees may attain a height of 50 to 60 feet and a trunk diameter of 24 to 30 inches in five or six years. The wood produced under such conditions is very light and soft, weighing only 6 to 8 pounds per cubic foot when dry. Timber of slow growth, whether from the outer part of old trees or from young ones that developed under adverse conditions, may weigh 25 pounds per cubic foot. These natural variations affect the structure, appearance, properties, and uses of the wood. To secure a uniform product, the trees must be grown in plantations."

The tree is very susceptible to injury during growth, and even slight injury during the first 6 months may cause death. When trees are fully mature, a small injury "may cause the wood to develop a hard and fibrous texture, and thereby lose its commercial value" *(4)*.

After the tree is about 7 years old, it loses its merchantable value because at that time, due to the development of a tap root, the center of the tree near the base becomes water-saturated; the wood in this portion becomes red in color and decay develops rapidly. As the tree becomes older, this zone spreads diametrically and up the bole *(4)*. Stearns *(7)* reports that a tree growing on poorly drained clay soils develops what is called "water heart" and becomes worthless.

Selection of Material for Testing

Five grades of balsa have been designated by the U. S. Foreign Economic Administration, namely, "A" grade, "AA" grade, "B" grade, "C" grade, and "Shorts." As mentioned previously, all the material used in this study was obtained from "AA" grade balsa billets. A description of the "AA" (Aircraft) grade in effect in 1943, as taken from Stearns *(7)*, follows:

"1. Width—Random, minimum 3 inches.
2. Length—Random, minimum 3 feet.
3. Scattered pin worm holes will be admitted, provided the concentration in any single square foot of surface measure shall not exceed 10.
4. Only 1 knot or hole under 2 inches in diameter will be admitted for each full 6 feet of length of any piece.
5. Surface pith and pith grooves on faces and/or edges shall not exceed in the aggregate 1/12 of the length of the piece.
6. The aggregate length of all splits or checks shall not exceed 1/12 of the length of the piece.
7. Wane shall not be admitted. Each piece must be full square-edged.
8. Moisture content and condition of finish shall be as ordered."
9. Only lumber weighing less than 9 pounds per cubic foot "dry"[1] weight will be admitted *(2)*.

At the outset, it was evident that there are at least four factors capable of contributing to the variability in the tensile strength of balsa. First among these is specific gravity, which in the case of balsa has a very wide range not

[1] "'Dry lumber is defined as lumber in a state of dryness which will permit close piling and bundling during the time necessary for delivery to destination without deterioration from decay. *(2)*.'"

only between trees and within the same log, but often in the same stick. Second is the possible effect of certain anatomical variations, either inherent or environmental. This is the influence of decay with its variable effects on strength properties of most woods, either with or without a commensurate effect on specific gravity. Fourth is the effect of compression failures, which are quite prevalent in balsa stock.

This study is concerned with the strength variability in balsa wood in which the variability is traceable principally to the effects of the first two factors mentioned above. The balsa available for testing was therefore carefully screened to eliminate material containing macroscopically visible compression failures or decay. In an attempt to refine somewhat the identification of decay, the balsa was also scrutinized under an ultra-violet lamp, a method which tends to sharpen the contrast of decayed zones. In some sticks a faint white fluorescence was detected which delimited areas radiating from the pith in an irregular pattern somewhat the way heart rot would appear. Such material was eliminated as abnormal from the investigation.

In order that a means of differentiation indicative of tensile strength might be developed, the remaining material was subjected to a series of experimental tests.

The history of the material showed that it was rejected for aircraft use due to the presence of corcho in all the sticks. Since the corcho was identified by means of a scribe test, that test was used in a first attempt to isolate this type of material but was soon discarded. Through experiments with transmitted and ultra-violet light on very thin cross sections of various sticks, a further attempt was made to establish a zonation indicative of strength. The transmitted light showed a concentric zonation clearly enough, but the results were not sufficiently comparable between sticks to permit the establishment of a classification series applicable to all the material. The ultra-violet light that was used produced no reaction that appeared to be indicative of strength differences.

Finally, by experimenting with various types of saws, making cuts across the ends of the sticks, a method was devised which appeared to be related to strength. The most pronounced and desirable segregation was obtained with a

Fig. 1.—Circular groover saw used in cutting the ends of balsa sticks.

13-in. circular groover saw (Fig. 1) cutting a kerf of ¼ in. and driven by a 2-hp., 3-phase electric motor designed to operate at 3450 rpm. This saw severed the end of the piece in such a way that the fibers were broken, not cut. The broken fibers showed all gradations of failure, from a very fibrous one to a brash type with no protruding fibers. The zonation produced in this way had a concentric pattern as may be seen in Figs. 2 and 3, suggesting that the differentiation was somehow related to growth.

An arbitrary sawed-appearance classification based on the nature of the fiber failure showing on the end grain, was then formulated (Figs. 2 and 3):

A. Surface almost entirely fibrous in character with little if any brash failure showing.

B. All variations intermediate between the A and C classes.

C. Surface showing no protruding fibers and having a brash appearance.

Fig. 2.—Typical appearance of end grain showing the strength-class segregation after being cut with the saw pictured in Fig. 1.

Fig. 3.—Typical appearance of end grain showing the strength-class segregation after being cut with the saw pictured in Fig. 1.

In the B and C groups, squarely broken ends of vessels may be clearly discerned, whereas in the A material very few if any vessels are exposed. An examination of Figs. 2 and 3 will clarify this point.

Five specimens were first selected from each of the three groups—A, B, and C—in order that a preliminary comparison of tensile strengths might be made. Later the number was expanded to include 15 specimens in each sawed-appearance category to provide a basis for valid analysis.

Preparation of Test Specimens

Devising a satisfactory tensile test specimen proved the most difficult problem in this portion of the study. In order to secure values representative of tensile strength along the grain, it was necessary that the specimens consistently exhibit tension-type failures at or near the minimum tension area of the specimen.

All experimentation in test-specimen design was carried out on the strongest available material as indicated by density and type of fiber failure on the end grain. (Early testing had indicated that the specimen design was not im-

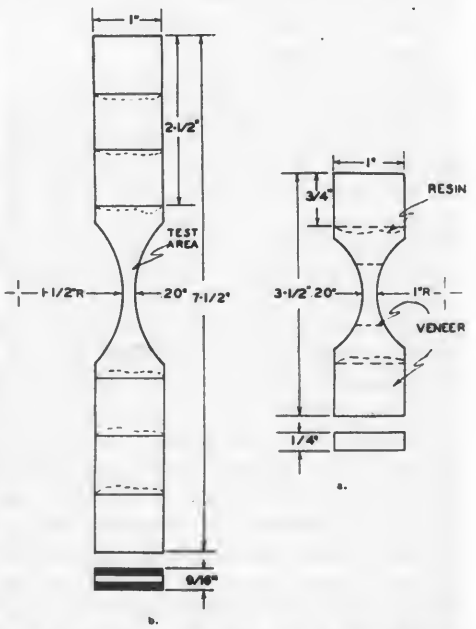

Fig. 4. Sketch of the two types of test specimens. a. Oiginal design. b. Final design.

portant in producing satisfactory tension failures in corcho material.)

Two basic types of test specimens were designed: the first for use in an Olsen plywood shear testing machine and, after this proved unsatisfactory, the second for use in the Templin grips of a Baldwin–Southwark hydraulic universal testing machine. Diagrammatic sketches of both types of test specimens appear in Fig. 4.

The principal difficulty in design was encountered in the modification of the grip area in such a way as to produce consistent tension failure at the minimum tension area. The problem here was twofold: 1) to strengthen the grip area in order to avoid shear failures (it was necessary that this strengthening be as gradual as possible in order to avoid stress concentrations); 2) to harden the grip area in such a way as to avoid the crushing of the fibers by the grips, which creates points of weakness.

After considerable experimentation with resin impregnation, it was apparent that some other more positive method must be devised for increasing the density of the wood at the grips. This was accomplished by making each grip face from three pieces of yellow birch veneer, one extending the full 2½ in., the next ⅔ that distance from end of specimen, and the last, ⅓ that distance from end of specimen (Fig. 5a). Specimens glued up in this manner, with a phenol-resorcinol resin, were placed in the hot press. In applying the pressure, care was taken to avoid crushing in the test area and at the inner edge of the grip area. By compressing the wood, the density of the balsa in each grip area was progressively increased from the inner portion of the grip area to the end of the specimen (Fig. 5). In this process the balsa at the grip area was gradually strengthened, with the resultant effect of lessening the stress concentration and giving sufficient shear strength to force the failure within the test zone. The use of 1/32-in. veneer for the grip faces was found to give the best results. The grip-area modification described above resulted in a specimen which gave consistently satisfactory failures as well as higher strengths than had been obtained previously. It was decided, therefore, to use this grip-area treatment in the final design.

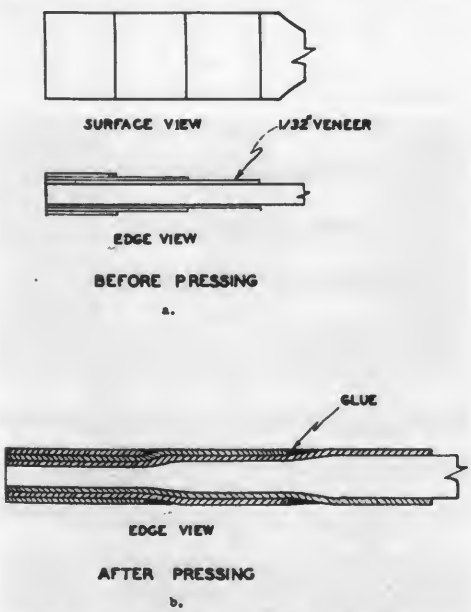

Fig. 5. A sketch showing the lay-up and final appearance of the test-specimen grip area.

A series of experiments with various dimensions, radii of curvature, and methods of shaping culminated in the acceptance of the following specifications as giving the most satisfactory results with the testing equipment available (Fig. 4b):

1) Test-area thickness: 0.25 in. (minimum for rigidity maximum for best failures)
2) Grip-area width: 1 in. (limited by the equipment)
3) Radius of curvature for the test area: 2 in. (To obtain the most uniform curvature in the test areas, with the least danger of pre-stressing, several specimens held together rigidly, were sanded across the grain on a block having the desired curvature.)
4) Tension-area width: 0.20 in. (minimum for rigidity; maximum for best failures)
5) Total length: 7.5 in. (This includes 2.5 in. of grip area on each end.)

The stock from which test specimens were cut averaged about 4 ft. in length. Test material consisted of two successive 9-in. blocks from one end of each stick selected for investigation. Since the sawed-appearance classes are concentric and extend longitudinally from

end to end of a given stick, the sawed-appearance classes defined in the first block were also found in the second block.

Test specimens were numbered in the following manner:

Stick No.	Position of 9-in. block in length of stick (Fig. 6a)	Classification	No. of specimen in this class and block
24 ------	b	B	4

To facilitate specimen sawing, some very wide planks were cut and lettered as illustrated in Fig. 6b. This letter is upper case and follows the stick number with no separating hyphen: 10C–b–B–4.

No data exist for the adjustment of strength values of balsa to a constant moisture content. Therefore, to exclude the possibility of variation in strength due to moisture content, all the specimens were conditioned to a constant moisture content of 10.6 percent prior to testing.

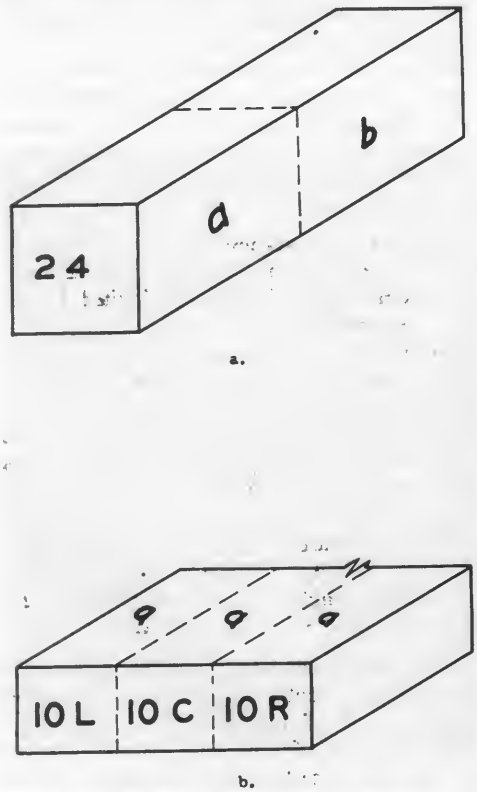

Fig. 6. Method of numbering the sticks.

Testing

Five specimens from each group were prepared and tested in order to evaluate the sawed-appearance method before proceeding with further testing. Thirty additional specimens, ten from each group, were then prepared and tested.

The 240-lb. range, graduated at 0.2-lb. intervals, of a 60,000-lb. Baldwin–Southwark testing machine and Templin grips were employed for the testing. An arbitrary machine speed of 0.05 in. per min. was used. Extreme care was exercised to avoid pre-stressing in placing each specimen in the grips. The grips were carefully aligned with a square and straight-edge in order to prevent any torsion effect. Minimum tension area was measured to the nearest 0.001 in. by means of a caliper and a thickness gauge for the minimum width of the test zone and a micrometer for the specimen-thickness measurement.

The specific gravity for each specimen was calculated to the nearest 0.001 on the oven-dry weight, oven-dry volume basis. Weight measurements were first made with a torsion balance accurate to the nearest 0.01 gram but which could conceivably be read to the nearest 0.005 gram, and volume measurements with a Breuil Mercury Volume-Meter having an accuracy of 0.003 cu. cm. With the remaining 30 specimens, however, an analytical balance was

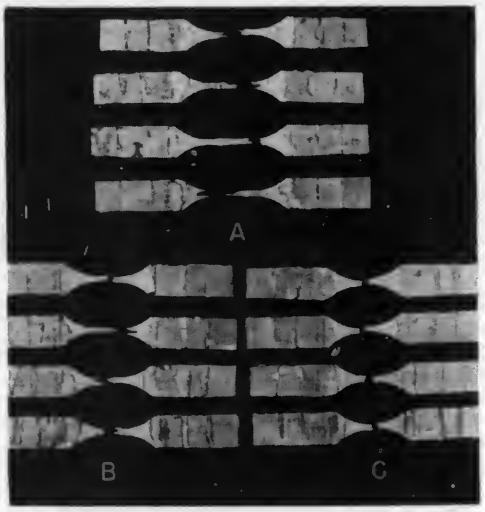

Fig. 7.—Typical test failures of each of the three sawed-appearance classes.

used for the weighing to permit greater accuracy in specific gravity calculations; it was read to the nearest 0.001 gram. As a precaution to insure accurate volume measurements, the exposed end grain of these specific-gravity sections was filled with ordinary wood filler and the sections returned to the oven for drying.

Results

Test results are presented in Table 1. Average tensile strengths of 3958, 2064, and 1305 p.s.i. were found for sawed-appearance classes A, B, and C, respectively. Fig. 7 exhibits typical failures obtained for each major sawed-appearance group in the preliminary testing.

Analysis of Results

In order to provide a convincing interpretation of the test results, the data were statistically analyzed using the method of analysis of variance as described by Snedecor *(6)*.

Analysis of the data obtained from the mechanical testing, provides statistical evidence to support the following conclusions:

1. The sawed-appearance classification separates the material into three distinct tensile-strength groups: A, high; B, intermediate; and C, low strength.

2. The specific gravity of the A, or high-strength, material was significantly higher than that of either of the two weaker classes. The

TABLE 1.—ACTUAL TENSILE STRENGTH AND THEORETICAL SPECIFIC STRENGTH VALUES FOR BALSA

Specimen number	Specific gravity[1]	Tensile strength p.s.i.	Tensile strength specific gravity	Type of failure
Sawed-Appearance Classification A				
3a-A-8	0.148	4630	31 220	Shear followed by tension
3a-A-3	.149	5070	33 936	Tension
3a-A-4	.151	4870	32 209	Tension
3a-A-5	.160	5860	36 511	Shear followed by tension
10C-a-A-1	.084	1894	22 656	Shear followed by tension
10C-a-A-3	.131	3115	23 797	Tension
10C-a-A-4	.097	3470	35 810	Tension
10C-b-A-3	.150	4300	28 686	Shear followed by tension
10C-b-A-6	.099	2480	25 000	Tension
10C-b-A-8	.143	4720	32 961	Tension
10R-b-A-7	.191	4820	25 249	Tension
10R-b-A-8	.162	3535	21 794	Shear followed by tension
24a-A-2	.144	3440	23 972	Tension
24a-A-4	.132	3100	23 520	Shear followed by tension
24b-A-1	.119	4060	27 285	Shear followed by tension
Average	.139	3958	27 307	
Sawed-Appearance Classification B				
10C-a-B-1	.095	2335	24 579	Shear followed by tension
10C-a-B-2	.088	1730	19 614	Tension
10C-a-B-3	.092	1935	20 964	Shear followed by tension
10C-a-B-4	.086	1424	16 462	Tension
10C-b-B-1	.077	1340	17 335	Tension
10C-b-B-2	.076	1465	19 327	Tension
10C-b-B-4	.089	1780	19 912	Tension
10C-b-B-3	.091	1700	18 661	Shear followed by tension
24a-B-1	.120	2155	18 018	Tension
24a-B-2	.116	2770	23 859	Tension
24a-B-3	.122	2140	17 584	Tension
24a-B-4	.099	1677	16 905	Tension
24b-B-1	.105	2620	24 929	Tension
24b-B-2	.107	2500	23 343	Tension
24b-B-3	.117	3385	28 981	Tension
Average	.099	2064	20 698	
Sawed-Appearance Classification C				
24a-C-5	.069	1193	17 290	Tension
24a-C-7	.101	1425	14 165	Tension
24a-C-8	.088	1230	13 893	Tension
24a-C-9	.086	1060	12 354	Tension
24a-C-10	.100	1740	17 383	Tension
24a-C-12	.092	1580	17 174	Tension
24b-C-1	.086	1190	13 805	Tension
24b-C-2	.086	1410	16 414	Tension
24b-C-3	.095	1321	13 964	Tension
24b-C-4	.100	1865	18 557	Tension
24b-C-5	.089	1330	14 977	Tension
24b-C-6	.093	1442	15 456	Tension
24b-C-8	.083	1038	12 566	Tension
24b-C-9	.082	988	12 093	Tension
24b-C-10	.070	760	10 857	Tension
Average	.088	1305	14 772	

[1] Oven-dry weight and oven-dry volume basis.

latter, however, could not be separated from one another on the basis of specific gravity.

In considering these conclusions, the question may arise as to whether the sawed appearance as an indicator of strength is a reflection of a combination of factors influencing tensile strength, or whether it merely reflects the influence of specific gravity. As was pointed out earlier in this paper, there is at least one other factor, anatomical structure, that could influence tensile strength.

It is therefore important to ascertain whether or not the method is also influenced by the anatomical structure or other unrecognized factors. This was accomplished by application of the specific-strength concept: with the relationship of strength to specific gravity known, strength test values may be converted to those associated with a common specific gravity of 1.00 by dividing each strength value by the corresponding specific gravity raised to the power which expresses the relationship *(1)*. Thus, if specific gravity were the only factor influencing the strength of balsa, no significant differences would exist among the sawed-appearance classes. The exponents expressing the relationship between specific gravity and strength have been worked out for most properties but not for tensile strength along the grain; therefore a graph representing this relationship was prepared, using the data from this study (Fig. 8). A straight line was found to be a satisfactory expression of the relationship; hence, an exponent of one was used in converting the values.

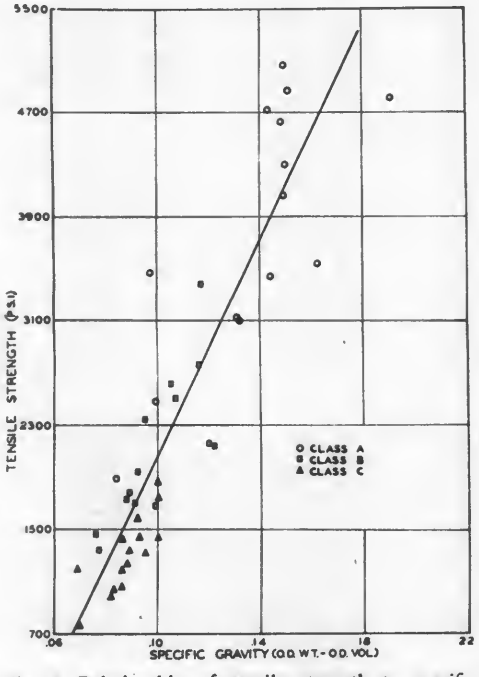

Fig. 8. Relationship of tensile strength to specific gravity in balsa specimens tested.

Specific-strength values, shown in Table 1, averaged 27,307, 20,698, and 14,772 p.s.i. for class A, B, and C material, respectively. Statistical analysis of these data indicated that a highly significant variation among all three classes was retained. This establishes the fact that the sawed-appearance classification is not influenced solely by specific gravity but also in part by other factors as yet unknown, possibly anatomical in nature. Therefore, at any given specific gravity there may be a wide range in strength. This is evident on examination of Fig. 8.

In an effort to provide an anatomical explanation for the specific-strength variation, an examination was made of the anatomy of three test specimens selected from the A class and compared with representatives of similar specific gravity, from the B and C classes, as well as of three typical specimens (one from each class) representing the specific-gravity range involved in this study. Results of this examination are summarized in Table 2.

Since the anatomy of balsa wood, as described by Record and Hess,[2] is characterized by the presence of abundant parenchyma, "mostly in metatracheal lines or narrow bands spaced one or two fiber rows apart . . .," it seemed plausible that the relative percentages of fiber and wood parenchyma might be found to have some relationship to tensile strength. The structural morphology of fiber cells and parenchyma cells gives a clue to their relative strengths which would substantiate such a theory. The thin-walled, square-ended, brick-like parenchyma cells must contribute appreciably less strength to the wood than the thick-walled, long, pointed, and overlapping fibers. Although these gross structural features account for some of the strength of fibers, the steep orientation

[2] Unpublished manuscript.

TABLE 2.—SPECIMENS SELECTED FOR MICROSCOPIC STUDY, INCLUDING MEASUREMENTS OF FIBER PROPORTION, NUMBER, AND AVERAGE WIDTH

Speciman number	Specific gravity	Tensile strength p.s.i.	Tensile strength specific gravity	Measurements: Fiber proportion percent	Measurements: Number of fibers	Measurements: Average width microns
A Typical Representative of Each Sawed-Appearance Class						
3a-A-5	0.160	5860	36 511	48	30	32
24b-B-1	.105	2620	24 929	33	21	31
24a-C-5	.069	1193	17 290	26	17	31
Selected Specimens with Similar Specific Gravities but Representing Different Sawed-Appearance Classes						
10C-a-A-1	.084	1894	22 656	44	21	42
10C-a-B-4	.086	1424	16 462	41	18	49
24a-C-9	.086	1060	12 354	32	16	41
24b-C-8	.083	1038	12 566	29	15	39
10C-a-A-4	.097	3470	35 810	39	22	36
10C-a-B-1	.095	2335	24 579	41	19	43
24-b-C-3	.095	1321	13 964	30	15	42
10C-b-A-6	.099	2480	25 000	41	20	38
24-a-C-7	.101	1425	14 165	29	14	42
24-a-C-10	.100	1740	17 383	32	14	44

of the cellulose crystallites in the secondary cell walls is ultimately responsible for the high longitudinal tensile strength of wood fibers. Ritter and Mitchell *(5)* have demonstrated, with the aid of polarized light, that the cellulose crystallite orientation in the ray parenchyma cells of basswood is perpendicular to the long axis of the cells. It was theorized that this same orientation would be shown in the wood parenchyma of balsa, and if this could be demonstrated, it would follow that the proportion of such material in a given specimen is reflected in its tensile strength.

Using the technique described by Ritter and Mitchell, an attempt was made to substantiate the above theory. Microscopic examination of several radial sections under polarized light immediately gave credence to the hypothesis, for the results obtained corresponded exactly to those described by the above investigators. That is, when the sections were rotated on the stage of the microscope so that the fibers and parenchyma were at one of their maximum brightness positions (45° to the Nicol prisms crossed at right angles) and a selenite compensator inserted in the optical system, the fibers appeared blue and the wood parenchyma yellow, or the reverse depending on which maximum brightness position was used. According to Ritter and Mitchell's interpretation, the orientation of the cellulose crystallites in the wood parenchyma cells would be at right angles to the long axis of the cells. The pit apertures in the parenchyma cells as seen in Figs. 9, 10, and 11 also confirm the orientation.

Fig. 9.—Radial section of a typical class A specimen (3a–A–5) having high tensile strength and high specific gravity.

This microscopical examination of radial sections indicated that variations in parenchyma and fiber proportions exist between specimens varying in tensile strength. This was apparent in specimens of equivalent specific gravity as well as in those differing in specific gravity.

Since it is most logical to use the cross section for estimating relative proportions of longitudinally oriented cells, the initial portion

Fig. 10.—Radial section of a typical class B specimen (24–b–B–1) having average tensile strength and average specific gravity.

Fig. 11.—Radial section of a typical class C specimen (24a–C–5) having low tensile strength and low specific gravity.

of this anatomical study was concerned with attempts to identify the two types of tissue on cross sections of the selected specimens. Common differential staining techniques and polarized light failed, however, to provide sufficiently accurate identification for reliable estimates of the proportion of fiber or parenchyma. For this reason, radial sections were used in an effort to correlate fiber proportion as shown on the radial surface, with tensile strength. Although the types of tissue can be readily identified on radial sections, the measurements and observations made were greatly facilitated by the technique described previously, using polarized light and a selenite compensator.

Microscopical examination of sections of the typical specimens of each class revealed that both the B and C classes had appreciably less fiber and more parenchyma than the A class. This difference is evident on examination of the photomicrographs (A material, Fig. 9; B material, Fig. 10; C material, Fig. 11) and explains not only the low specific strength of class C material but also the abnormal longitudinal shrinkage shown by low-density balsa as reported by Limbach and Paul *(2)*. Similarly, the differences observed between the A and C classes were also apparent upon examination of the sections of specimens of equivalent specific gravity but with varying tensile strength, as may be seen in Figs. 12 and 14. Between the A and B classes, however, differences were not so evident (Figs. 12 and 13).

In order to substantiate these observations, measurements were made of fiber proportion, number, and average width. The measurements were made along a radial line 2 mm. in length, covering what appeared to be typical material for the specimen. The proportion of this distance occupied by fibers was computed and expressed as a percentage. Also the number of fibers and their average width were recorded. These data are found in Table 2. The differences observed in the photomicrographs of the specific-gravity-range specimens are substantiated by the measurements. Of the specimens of equivalent specific gravity, the fiber proportion of the A material is in every case about ten percent greater than that of the C class. Also the A material has approximately a third

Fig. 12.—Radial section of a class A specimen (10C–a–A–4) having a specific gravity equivalent to that of the specimens pictured in Figs. 13 and 14, but with a significantly higher tensile strength.

Fig. 13.—Radial section of a class B specimen (10C–a–B–1) having a specific gravity equivalent to that of specimen 10C–a–A–4 (Fig. 12), but having a significantly lower tensile strength.

Fig. 14.—Radial section of a class C specimen (24–b–C–3) having a specific gravity equivalent to that of specimens 10C–a–A–4 (Fig. 12) and 10C–a–B–1 (Fig. 13), but having a significantly lower tensile strength.

more fibers on a numerical basis. The differences in average fiber width do not seem significant. Between the A and B classes, however, there does not appear to be any significant difference to explain the strength variation, nor do the photomicrographs reveal any apparent differences. Possibly this unexplained strength variation may be related to certain features not investigated, such as cell-wall thickness, cell diameter, or fibril angle in fibers, although no large deviations in fibril angle were evident.

The variation in proportion of parenchyma shown by specimens of similar specific gravity accounts for much of the strength variation due to factors other than specific gravity. The varying proportions of protruding fiber revealed on the end grain of balsa when sawed, used in this study as the basis for determination of sawed-appearance classes, are also in large part the result of varying amounts of parenchyma.

During the course of the study, two observations were made which further magnify the significance of the method:

1) The success of the method may be explained to some degree by comparison of the

end grain after sawing (Figs. 2 and 3) with the failures in the test specimens (Fig. 7). The type of failure, whether brash or splintery, corresponds almost exactly to the appearance of the end-grain sawed surfaces.

2) Since the method gives an immediate estimate of the transverse disposition of high-strength balsa throughout the length of any given stick, its application in rapid segregation of this material is evident.

Conclusions

1) High proportions of parenchyma in relation to fiber are to a considerable extent responsible for the low tensile strength of so-called "corcho" in balsa wood.

2) The sawed-appearance classification developed in this study presents a simple yet remarkably precise means for differentiating balsa on the basis of tensile strength.

Literature Cited

(1) Forest Products Laboratory. Design of Wood Aircraft Structures, ANC–18. 247 pp. Aeronautical Board. Washington. (1944)

(2) Limbach, J. P. and Paul, B. H. Variation in the Specific Gravity of Balsa and Its Relation to Longitudinal Shrinkage. Tropical Woods 84: 18–23. (Dec. 1, 1945)

(3) Pierce, J. A. An Evaluation of the Type Material of *Ochroma,* the Source of Balsa Wood. Tropical Woods. 70: 20–23. (June 1, 1942)

(4) Record, S. J. and Hess, R. W. Timbers of the New World. 640 pp. New Haven: Yale University Press. (1943)

(5) Ritter, G. J. and Mitchell, R. L. Crystal Arrangement and Swelling Properties of Fibers and Ray Cells in Basswood Holocellulose. Paper Trade Journal 108: 33–37. (Feb. 1939)

(6) Snedecor, G. W. Statistical Methods. 485 pp. Ames: The Iowa State College Press. (1946)

(7) Stearns, J. L. Balsa, Its Growth Characteristics and Uses. Southern Lumberman 167: 216–220. (Dec. 15, 1943)

Report of Committee on Coordination of Forest Products Research

AT THE second annual meeting of the Society in Chicago in 1948, an open forum on Coordination of Research in the Field of Forest Products was held on March 23. A number of brief papers on the need for coordination were presented, and a general discussion followed, all of which may be found in the Proceedings of the Society, Vol. 2 (1948) pages 137 to 149 inclusive. Subsequently the President appointed a Committee on Coordination of Forest Products Research and charged it with "the responsibility of formulating a proposed action program for presentation at the next annual meeting . . ."

The members of this committee are so widely scattered that committee meetings could not be held conveniently and the work of the committee was necessarily done by mail. The first task undertaken was to work out a statement indicating what we mean by coordination of research and outlining a policy on the subject for consideration and possible adoption by the Society. That statement is attached to this report for your consideration and discussion.

As long as we remain a free people there will be no over-all coordination of research by dictation. Perfectionists may want the Society to take a more positive stand than is indicated in the policy statement, but the Society is completely without authority to dictate to any research group. Our only tools for reducing unnecessary duplication and overlapping of research effort are education, discussion, and example. The very fact of the organization of the Society and the continued efforts to increase its membership and build up its influence strongly encourage coordination of research effort by bringing together widely varied groups and individuals who are sponsoring or conducting forest products research. Through the papers presented at the national and local meetings and through individual and group discussions they become better acquainted with what others are doing and accomplishing and thus better able to avoid unneeded repetition of their work. Through the same means their thinking should be stimulated and new ideas developed that will point the way to new and profitable research or development through the application of research findings.

As the Society becomes stronger financially, its monthly bulletin can become more effective as a means of keeping its members currently informed about the character and progress of forest products research and development throughout the world. Ultimately we should be able to provide a full time editor with necessary assistants whose sole task will be to build up the monthly bulletin into an interesting, attractive, and powerful instrument for carrying on the work of the Society and attaining its objectives. Coordination of research is one of the important objectives. The task of developing a monthly bulletin that will be interesting and useful to all members is difficult because ours is a "horizontal" organization that cuts across all professions, trades, and commercial interests concerned with the production, manufacture, distribution, utilization, and study of the products of the forest. It is all the more urgent for that reason since there is no other means of bringing these diverse interests together in a united effort for progress. The committee, therefore, considers the development and improvement of the monthly bulletin an important part of any program to encourage the coordination of research.

Much of the duplication of research effort that exists seems to result from lack of information on what has been done or is being done on any specific problem. Through publication of papers and abstracts and making them currently available to the members of the Society much can be done to dispel ignorance of what is going on. A further and more pointed attack on ignorance among research workers would be the preparation and publication of authoritative monographs bringing together in summarized form the knowledge of the world on some particular subject of especial interest to forest products researchers. They may vary in size from small pamphlets to full-sized books, according to the subject matter, the author, and the available means for financing and publish-

ing. They may also vary in character from popular treatises for the lay reader to the most detailed scientific publications for the specialist. Such publications would facilitate the task of the novice in learning what is known and would make it easier for him to avoid starting research on problems that have already been solved. They would also serve as basing points for new research or development and would undoubtedly stimulate the thinking of research workers. The less technical treatises would be useful to the members of the Society and others who are not engaged directly in research but are interested in it or may be sponsoring it.

While the need for some such monographs is evident, the problem of financing their preparation and publication is not simple. Most of them probably would have limited sale and would fall considerably short of being self supporting. Possibly some monographs could be prepared by special committees of the Society. Others might be undertaken by interested individuals who have special knowledge in the field and the ability to summarize and present it effectively. Other organizations, alone or in cooperation with the Society, should also be encouraged to produce some of the desired publications. Within its financial and other limitations the Society should encourage the publication of needed monographs by all suitable methods and agencies.

Another device for bringing researchers in a given field up to date is the "round table discussion." By this we mean assembling a limited group of active research workers concerned with a given problem for the purpose of discussing their research methods and results. Such meetings can sometimes last several days to advantage and their participants can go into greater technical detail with regard to methods and results than is usually desirable in large public meetings. They may, when desirable, be in the nature of a formal symposium with prepared papers limited to a given subject. The meetings can bring out differences of opinion as to the value and usefulness of different methods or the meaning of results. They serve to open the eyes of the beginners and sharpen the ideas of the more experienced. Round table discussions, when confined to a single subject and efficiently planned and handled have been found exceedingly helpful to research workers. In some of the less difficult subjects they can also be very interesting and informative to a non-participating audience.

The committee believes that the Society should encourage the round table method of holding research discussions at local, national, and international levels and should cooperate fully with any other organization interested in or sponsoring such meetings. It should be emphasized that these are usually small meetings and may be held at any suitable time or place. They may be but need not be held in connection with the annual meetings of the Society or the local meetings of its sections. Their important function is to get experts together for informal but detailed and intimate discussions.

Throughout its consideration of its assignment, the committee has kept in mind the fact that coordination of research is only one of the objectives of the Society and can only hope for its proportionate share of the Society's thought and energy. It is an important objective, however, and should receive its full share of attention if the Society is to serve its members adequately.

It is not the desire of the committee that the attached policy statement on Coordination of Forest Products Research shall be adopted immediately as the policy of the Society. It can undoubtedly be improved by thought and discussion. It is our hope that it will receive thorough discussion at the present meeting and through the coming year. There is no need for haste. Possibly with amendments it can be offered for formal adoption next year. In offering this policy statement the committee is fully aware that the recommendations cannot be put into effect immediately. They must serve as goals to work toward rather than as directives requiring immediate action.

Policy Statement

Coordination of Forest Products Research

It is the policy of the Forest Products Research Society to encourage and to stimulate forest products research in every practicable way so that by means of increased funds, more cooperative effort, and higher efficiency in the use of available time, personnel, facilities, and money, more rapid progress and greater accomplishments can be achieved. The Society is

gratified when increased funds are made available to private and public agencies for expansion of forest products research activities, but it is firm in its conviction that the funds available to any agency at any time must be spent with maximum effectiveness. Each agency, through voluntary coordination with the efforts of all other agencies in its field, can assist materially in realizing a greater over-all efficiency.

The Society fully appreciates that in a free democracy there can be no dictated or compulsory coordination of the research activities of different agencies. Each research establishment, public or private, is responsible to those who finance its program and, within the limitations imposed by its financial sponsors, it is free to select and to work on its own projects. The Society also recognizes that, for business and financial reasons, much private and industrial research will be kept confidential and that results of such research will not be published. Research programs of public agencies, however, are usually not confidential, and results are published currently. Despite these limiting factors, there is much latitude, through individual coordination and cooperative action, for avoiding duplication of research effort.

The Society has no authority over any research agency and no powers of coercion. It must, however, constantly keep the need for research coordination before its members and the public and must encourage and facilitate cooperation and coordination by all practical means at its disposal. Important among these means are:

1. Providing for discussions of research objectives, programs, and results at annual meetings of the Society and in the publication of its Annual Proceedings.

2. Presenting papers and discussions at local meetings of Society Sections.

3. Publishing appropriate new items and abstracts in the Society's monthly bulletin.

4. Increasing the availability of abstracts of publications relating to forest products research and development.

5. Sponsoring the publication of monographs or reviews on specific subjects to review the current knowledge of each subject, to provide a solid background for developing new projects, and to avoid useless repetition.

6. Sponsoring and encouraging round table meetings of experts engaged in or interested in specific subjects or lines of research, for informal discussion of their progress, methods, and problems.

7. Searching for other practical methods of bringing about greater cooperation and coordination.

Duplication or repetition of research is often desirable in order (a) to check the work of previous investigators, particularly when more precise equipment or procedures have been designed, (b) to attack a problem with a different approach, or (c) to attempt to apply previously reported research results to local needs and conditions. Repetition of research because of ignorance of what has been or is being done, because of a lack of vision to plan something different, or because of an effort to beat someone else to the goal is undesirable and wasteful. The Society must do everything possible to discourage such sterile activities.

COMMITTEE ON COORDINATION OF FOREST PRODUCTS RESEARCH
GEORGE M. HUNT, *Chairman*
WILLIAM J. BAKER
ALBERT G. H. DIETZ
GRANT DIXON
H. C. MOSER
HARRY F. LEWIS
T. R. TRUAX

Discussion

George M. Hunt (Forest Products Laboratory): I had hoped that a number of committee members could be here today to present their ideas on the relative emphasis that should be placed on some of the items in the report. While we agreed on the report as a whole, some of the committee members feel that certain parts of our recommendations could properly receive more emphasis. In that connection I want to read into the record some comments of Dr. Dietz, a member of the committee who could not be with us today. In a recent letter he said:

"I do not think I have anything to add to the discussion of the report of the Committee on Coordination of Research. In previous correspondence, I have indicated that it seemed to me that the position of funda-

mental research was rather poorly defined, and not too well coordinated. This is the type of work that is apt to be carried on in universities and similar places where immediate goals are not too pressing and the research man can go in the direction of fundamentals. It seems to me that a good deal of this work never comes to light because it may be carried on by either graduate or under-graduate students under the direction of a professor who happens to be interested in some particular problem. Frequently, this kind of work may yield negative results, and consequently is never discussed. In other cases, it may yield interesting positive results, but the results are not sufficiently advanced to warrant publication. The consequence is that there may be a good deal of work duplicated in various places merely because no one knows what has been done before. This type of research, even though it is of a rather low level in many instances, might at least provide ideas to other workers if there were some way of making it known.

"It may be that the Forest Products Research Society could find ways of unearthing this kind of information and passing it along to other interested groups."

Armin Elmendorf (Elmendorf Research, Inc.): I would like to commend the Committee for the constructive suggestions made in its report. The report states quite correctly that much private and industrial research will be, and must of necessity be, kept confidential. Private agencies therefore depend to a very great extent for the stimulus that every research worker needs, upon the published results of work done in publicly supported laboratories. I would therefore like to stress the need and importance of making the complete record of work done on significant problems, available to those currently active in each of these fields.

Competition among research workers is in my opinion very desirable and of first importance in all creative work of this kind. I therefore see no real objection to the duplication of effort if several agencies should happen to engage upon work simultaneously in the same field. We can safely rely upon the fact that the individuality of each worker will cause him to emphasize and select variables for his study that are going to differ from those selected by others, and that the outcome of the various investigations is not going to be exactly the same. Interpretations of even the same data may vary considerably. If meetings could be arranged of the specialists or experts each active on some phase of a problem there can be a meeting of minds and new stepping stones can thusly be laid on the path of progress.

Ignorance of what is being done simultaneously by others is in my opinion no serious handicap or retardant of progress in science. Knowing that others are working in the same field may in fact spur research workers to a very healthy activity. But ignorance of what has been done by others in the past, whose work has been published, is costly ignorance and may very well lead to sterile activities.

It would be advisable and undesirable, even if it were possible, for the Society to assign research work to various agencies in order thereby to avoid duplication of effort. The Report of the Committee on Coordination points out that the Society has no authority over any research agency and no powers of coercion. I would like to add to this that even though the Society has no such powers, it should not even undertake discussion of any program of coordination which might be interpreted as a wish for separation of research activities into various agencies. Maximum progress requires maximum freedom to the spirit of inquiry.

I would like to suggest that greater emphasis be placed in the Committee's Report on the need for substantially complete bibliographies of the literature on important subjects of interest to those engaged in forest products research. Volunteers might undertake the compilation of such bibliographies from information obtained from the Society membership, and brief abstracts, of two or three sentences, prepared by properly qualified individuals, could be compiled. Such abstracts could be presented at Section meetings and in due course they could all be published by the Society. I would be grateful indeed if I had access to authoritative bibliographies of this type.

E. George Stern (Virginia Polytechnic Institute): The Committee on Coordination of Forest Products Research suggests that papers on and abstracts of current findings be currently made available to the Society members. Financ-

ing such dissemination of information seems to be the outstanding difficulty.

The Society has made arrangements with the editors of *Wood* magazine for publication of Society news. Further cooperation with the editors may result in a column in this magazine devoted to dissemination of information based on investigations performed during the past months or even being performed in various laboratories. Such a column could never claim to completely cover all investigations, since some will never be reported or published. On the other hand, a considerable amount of information on current investigations could be published in such a column by means of properly edited notes and abstracts. Individuals and organizations interested in the respective subject matters could, as a result of publication, contact the investigators for further information. An editorial note could refer to planned presentation of detailed data at later meetings of technical and research Societies and to planned publication in technical magazines and bulletins.

By the above means, current research findings could be brought to the attention of the public without any appreciable delay or cost to the Society.

State Forest Products Research in Michigan

Hereford Garland

Director, Forest Products Research Division, Michigan College of Mining and Technology

Although the forest resources and the forest products industries of Michigan have changed markedly since the time when it was the Nation's leading lumber producer, these are still major elements in the economy of the state. Forest products research has been officially recognized as an instrument for guiding changes in wood production and wood use toward economic development. Three state educational institutions are applying staff and facilities to the problems of wood utilization and two state departments are actively involved in the industrial application of forest products research results. The efforts of all of these Michigan agencies are coordinated, and reviewed by industry representatives.

THE history books give us a rather dismal picture of Michigan as a land where the timber barons cut out and got out leaving behind stumps, tax delinquent land and a wood-using industry without wood to use. This picture never was quite right and, of course, it presents an entirely false impression because it is static and takes no account of the dynamic factors that have been active since the "good old" white pine days. The true story of forest products in Michigan is a moving picture in which changes are continually taking place. Forest products research can have an important part in developing and modifying the picture.

Significance of the Forest Products Industries

Timber Resources

It is true that the great bulk of the readily accessible standing timber has been removed but the timber growing lands for a great portion of the state have remained as such and have been more or less productive. Fire in the past has deteriorated the growing capacity of many thousands of acres but fire is now being controlled and these lands are slowly recovering. Much of the timber land that was once termed cut-over has again attained commercial importance with the yield of a second crop and other large forest areas may be expected to grow into this classification within the foreseeable future. In the southern part of the state the original timberland was mainly converted to farming but even here the inevitable farm woodlot has become a commercially significant timber producing factor.

The moving resource picture in Michigan shows timber growth approaching a balance with timber drain and indicates the probability of an eventual increase in wood supply for industry.

The relative importance of Michigan timber species has changed and will probably change further. White pine is little more than a memory but the northern hardwoods which were passed over by the early lumberman as inferior species are enjoying a better demand than white pine ever did. In recent years hemlock has gained a respectability denied it in a softwood lumber market dominated by pine. With the growing scarcity of spruce, pulp mills have cultivated an appetite for balsam and now the lowly "popple" or aspen has become a full fledged pulpwood species. How soon aspen will become recognized in the lumber trade as a suitable substitute for the vanishing basswood will depend somewhat on forest products research.

The stumpage value picture is dynamic too. No species has a negative value, and with a high component of maple and birch the northern hardwood timber stands undoubtedly contain more value per acre than any in the country with comparable volume.

Michigan's timberland ownership pattern has become progressively less fluid. Tax deeded cut-over lands which once were the natural aftermath of logging have now been fairly well blocked into state and federal forests and are being managed to sustain a future industry. Timberland values as well as stumpage values are being recognized by private owners and the meaning of tree reproduction is becoming increasingly significant. More and more timber operators are practicing some form of selective cutting. The modern tendency to retain timberland for its growth potential is disclosed in a recent study of ownership in the Upper Penin-

sula. Two million four hundred thousand acres, or 45 percent, of the privately owned commercial forest land is in ownerships of 1,000 acres or more. This is particularly significant in consideration of the fact that the old-growth hardwood forest type amounts to less than 800,000 acres in that area.

Although Michigan's proper nickname is the "Wolverine State", it is sometimes facetiously referred to by foresters as "The Forestry School State" because it is the only state offering professional forestry training in three different institutions. Actually, this constitutes recognition by the public and the career-seeking undergraduates that the forest resource and its utilization is a large factor in the economy of the state.

Wood-Using Industries

The primary wood-using industries, those depending directly upon the forests for raw material, have undergone transitions correlated with the changes in the resource and in the general economic position of the state. Gone are the huge pine mills which at their peak cut over 5 billion feet of timber annually. However, sawmilling is still an important activity. There were 1,900 active sawmills reported in Michigan for 1947, with a total production of 580 million board feet. Sixty-five percent of that production was hardwood and nearly forty percent of the total was birch and maple. The trend in sawmilling is toward smaller production units and smaller lower grade logs.

Sawmilling no longer dominates the forest products picture as it once did. There has been a strong trend towards diversification of the primary wood-using industries. Pulp mills constitute a major factor in the total cubic-foot wood harvest. The choicest portion of the sawlog stand is now consigned to veneer mills. Michigan has two of the largest and most efficient hardwood distillation plants in the country. Rough wood products such as mine timbers, posts, and ties account for a considerable timber harvesting industry.

The unused wood by-products from logging and primary milling present a challenge to the forest products researcher in Michigan as they do in all other timber producing states. However, the problem here fortunately is unique in that this potential raw material is readily accessible for concentration at a processing point and is located within a relatively short shipping distance of important product consuming areas.

The secondary wood-using industries of Michigan, those using lumber or other partially manufactured wood as raw material, are not particularly integrated with the timber resource. While most of the product of the northern forest is shipped out of state as rough lumber and pulpwood, the wood products manufacturing plants in the southern area import a large proportion of their raw material from other states. The Grand Rapids furniture industry which had its beginnings when Michigan timber was readily accessible to it as raw material has stayed in place and developed primarily because of manufacturing and merchandising "know how". Then with the industrial growth of the state a great variety of wood product manufacturing plants became established in southern Michigan. There were 542 plants producing finished wood products in this part of the state in 1939 and there is reason to believe that there has been some expansion since then. In the Upper Peninsula, the forest products industries are still predominately primary in character but there is a definite tendency to take advantage of the economies of remanufacturing the northern species near the source of supply.

The forest products industries form an important facet in Michigan's economy and they will undoubtedly continue to change and develop as they have in the past. Forest products research can help to guide the changes and stimulate development.

Forest Products Research as an Instrument of Economic Development

State Sponsorship

The first direct recognition of forest products research as a state activity in Michigan came in 1944. The Upper Peninsula Technical and Advisory Committee to the Michigan Planning Commission was at that time studying the economic problems of that area with the aid of a number of industrial sub-committees. Two of these sub-committees, one on forest products and the other on chemical and metallurgical processes, recommended that a state appropriation of $25,000 be made for a

study of the possibilities in the industrial utilization of wood. This recommendation was promptly passed through the regional advisory committee and the Planning Commission to the Governor and the Little Legislature. In October 1944 allottment of the requested funds was made to the Michigan Planning Commission and the Governor appointed a Forest Products Research Committee to advise the Commission on the use of the fund. The Committee was composed of representatives of the three state technical institutions, the Department of Conservation, and several branches of the wood-using industry with Dr. Grover C. Dillman, President of Michigan College of Mining and Technology, as Chairman.

The Advisory Committee's first action was to call upon a small group of consultants from state agencies to study the overall wood utilization problem in Michigan and to propose specific research projects. This group, working under the direction of Mr. Stanley G. Fontanna, Deputy Director of the Michigan Department of Conservation, reported to the Advisory Committee in 1945. Its findings were published as a bulletin of the Michigan Planning Commission in 1946 under the title "Wood Utilization Problems and Possibilities in Michigan".

The six most urgent projects recommended by the consulting group were assigned to three appropriate state research institutions with funds allotted for the work. Reports on these projects were published in 1947 as bulletins of the Michigan Department of Economic Development, as follows:

Inventory and Directory of Wood Using Industries of the Upper Peninsula of Michigan, by Hereford Garland, Michigan College of Mining and Technology.

Small Sawmill Improvements—A Progress Report, by Richard C. Johnson, Michigan State College.

The Michigan Wood Turning Industry—Status and Outlook for Expansion, by A. J. Panshin, Michigan State College.

Manufacture and Use of Small Dimension—A Progress Report, by Robert Craig, Jr., University of Michigan.

Wood Defiberization—A Progress Report, by Robert Craig, Jr., University of Michigan.

Utilization of Aspen—A Problem Analysis, by Hereford Garland, Michigan College of Mining and Technology.

National Conference

Besides periodically reviewing progress on the state projects, the Forest Products Research Advisory Committee of the Michigan Planning Commission considered the overall aspects of a state program. At a meeting in July 1945 it was suggested that other states might be concerned with similar programs to develop forest products industry. It was the recommendation of this Committee that the Planning Commission approach other state agencies and the Forest Products Laboratory proposing a national conference to exchange information on forest products research programs. The result of this recommendation was the Conference on State and Federal Forest Products Research Programs held at Madison on March 18 to 20, 1946. It was sponsored jointly by the Forest Products Laboratory and the Michigan Planning Commission. The collected papers of the conference provided a valuable fund of information on the current activities of virtually all public agencies engaged in forest products research.

During the course of keynoting the conference Dr. Dillman posed the question "Should we not consider the advisability of forming a permanent organization to facilitate the interchange of forest products research information?" Specific action was taken on this question when Dean Samuel T. Dana, one of the Michigan Planning Commission advisors, moved that a committee including representatives of industry and public agencies be charged with the responsibility of planning a permanent national forest products organization. From these beginnings the Forest Products Research Society was launched in early 1947. Michigan may be justly proud of the enthusiasm, as measured by the phenomenal growth of the Society, with which her pioneering suggestion has been received.

Michigan Forest Products Research Agencies

University of Michigan

Since the organization of the School of Forestry and Conservation at the University in 1927, wood technology has had a place in the

research program both at the staff and student levels. This work has had more emphasis since 1934 when a separate curriculum in wood technology was first offered. Graduate problems and staff projects have covered a wide range of topics, mostly on the mechanical and physical properties of woods and wood products, and wood fabrication procedures.

For the past several years the staff of the wood technology laboratory has been in a position to engage in contract research handled through the Engineering Research Institute of the University. One major project in progress at this time is a study of adhesives in furniture manufacture supported by the National Association of Furniture Manufacturers. Financial support for forest products research comes from regular state University appropriations and from cooperators.

In 1948 the school formally opened an expanded Wood Technology Laboratory devoted to teaching and research. The 17,000 sq. ft. of space provides separate laboratories for the study of wood structure, wood machining, wood finishing, and testing and gluing. Also included are a fully controlled dry kiln and experimental pressure treating plant, a tool grinding shop, and controlled temperature and humidity rooms.

Three staff members, William Kynoch, Robert Craig, Jr., and L. A. Patronsky, are assigned to teaching and research in wood technology on a full time basis. The work is under the administration of Dean S. T. Dana.

Michigan State College

The Department of Forestry here has carried on forest products research on the graduate level mainly since 1935. The graduate problems have included kiln drying, fire proofing, wood structure studies, forest products merchandising, maple syrup production, wood stabilization, radio frequency gluing, and lumber grade production studies. Staff projects have included industry surveys and the improvement of sawmill equipment.

Present projects are concerned with methods of chemical seasoning of lumber and the preparation of an extension bulletin on the construction and operation of lumber dry kilns. Financial support for forest products research comes from state and federal appropriations and governmental or industrial cooperators.

Wood utilization research facilities at Michigan State have been expanded in recent years. They include a modern dry kiln, a pressure treating plant, a general wood working shop, and a glue and press room. A new sawmill building houses a circular sawmill and provision is made for the installation of a band mill. Plans have been made for a finishing laboratory.

Staff members assigned to wood utilization and technology are A. J. Panshin and J. W. Creighton. They divide their time between teaching and research. Dr. P. A. Herbert is head of the Department of Forestry.

Michigan College of Mining and Technology

Forest products research activities were begun at the college with the initial phase of the Planning Commission program. The two projects assigned to the college were carried out by a staff member during 1945 and 1946.

In 1947 the present forest products research program at Michigan Tech was authorized by the State Legislature, and the Forest Products Research Division was established by the Board of Control of the College. It was specified that the work be directed at the utilization and marketing problems of wood industries in the timbered areas in the state. Planning and progress of the projects are reviewed periodically by an advisory committee composed of eleven representatives from the various branches of the wood-using industries and four representatives of other research agencies.

The present program consists of four projects: (1) Hardwood fiber production—a study of the possibilities of producing corrugating board from logging residues; (2) Utilization of low grade hardwood lumber—an investigation of the use of small cuttings through mechanized preparation and fabrication; (3) Timber harvesting—the mechanization of sawlog and pulpwood logging; (4) Industry development—spot studies and technical aid of a local or individual nature. Graduate problems involving wood utilization in the engineering departments of the college are guided by the personnel of the Forest Products Research Division.

Research facilities in the laboratories of the Mechanical, Civil, Electrical, and Chemical Engineering departments of the college are available for the program. Wood processing is carried on in the maintenance shops where some equipment required for research has been installed, including a radio frequency generator, gluing equipment, and special cutting tools. Financing of the program is handled as a special item in the state appropriation to the College.

The Forest Products Research Division is staffed by five full time technical men, Hereford Garland, A. W. Toole, W. H. Koepp, L. W. Hooker, and C. W. Danielson, Jr. The staff is responsible to Dr. G. C. Dillman, President of the College.

Michigan Department of Conservation

This Department took an active part in the Planning Commission program and continues to cooperate with other state agencies on forest products problems. Mr. S. G. Fontanna, Deputy Director, is a member of the Forest Products Advisory Committee of the Department of Economic Development.

The Forestry Division has recently initiated a research program under the supervision of Norman F. Smith. One project in progress is a survey of the wood-using industries of southern Michigan. The work of the Division on private forestry cooperation is in charge of T. E. Daw and his functions are intermittently concerned with forest products problems.

Michigan Department of Economic Development

The Michigan Planning Commission was abolished by the legislature in 1947 and some of its functions were assumed by this new agency. On the recommendation of the Forest Products Advisory Committee of the Planning Commission this committee was reconstituted under the new Department. This Committee is composed of industry representatives and representatives of all state agencies concerned with forest products research. Its function is to foster development of the wood using industries and to coordinate state research efforts. Mr. John W. Dregge, of Grand Rapids, is Chairman.

One staff member of the Department is a professional forester, George E. Billings, who is assigned to handle industrial development problems.

Cooperating Agencies

A discussion of forest products research in Michigan would be incomplete without mentioning the splendid cooperation of the U. S. Forest Service. Although the Lake States is the only eastern forest region that does not have the benefit of a Forest Utilization Service Unit, Michigan agencies have received much effective attention to problems of wood use presented to Director G. M. Hunt and the staff of the Forest Products Laboratory.

The Lake States Forest Experiment Station has frequently been called upon to supply data in connection with Michigan forest products problems. Director E. L. Demmon is a member of the Forest Products Advisory Committee of the Department of Economic Development.

The preparation of the Lake States Aspen Report series, which is a region-wide group effort under the leadership of the Lake States Forest Experiment Station, is a fine example of inter-agency cooperation on a common wood utilization problem.

TECHNICAL SESSION VI

Wednesday, May 4, 1949, 2:30 P. M.

General Subject: Seasoning and Related Problems

Chairman: Fred W. Gottschalk, Technical Director, American Lumber and Treating Company, Chicago, Illinois *(Past President, FPRS)*

Recorder: John H. Sweeney, Aetna Plywood and Veneer Company, Chicago, Illinois *(Chairman, Midwest Section, FPRS)*

Direct Gas-Fired Kilns in the South

Mark M. Lehrbas

Southern Forest Experiment Station, New Orleans, La.

The strong demand and premium prices for dry lumber, together with the move on the part of sawmill operators to produce finished produ.ts that they could sell at retail, is leading operators in the South to look toward k lns as a fast and profitable method of drying lumber. In recent years there have been rapid developments in direct gas fired kilns for the use of smaller concerns. The most common type is the natural draft with manifold heat. This and other types are described. Current operating costs are presented based upon a survey of 50 operations. Temperature control and other problems are discussed.

Introduction

I WOULD like to make it clear before presenting this paper on direct gas-fired lumber dry kilns that we in the Forest Utilization Service are not interested in recommending, promoting, or selling any particular type of lumber dry kiln. Our work with direct gas-fired kilns has been in connection with keeping posted or up to date on new developments in the wood seasoning field. Our interest is in the better utilization of all forest products and any improvement in the seasoning practices over existing conditions that increases the utilization is naturally of interest to us and considered as part of our normal program.

Until recently steam was practically the only medium used for heating lumber dry kilns in the South. Although other types of heat, including gas, oil, etc., are now used, steam is still by far the most universal and successful form of heating. Steam kilns are successfully used for precision drying of all species of lumber, whether air seasoned or green from the saw, and for all types of products. Usually, however, only those larger concerns which had steam available for the primary plant could afford to install steam kilns. The smaller operators, who used Diesel, gas, or other forms of power—and there are approximately 15,000 of them in our territory—were usually not in a position to install expensive steam kiln installations and had to be satisfied to sell their lumber either in a green or air-dried condition.

During and since the war, the strong demand and premium prices for dry lumber, together with the move on the part of sawmill operators to produce finished products that they could sell retail, led additional operators to look towards kilns as a fast and profitable method of drying lumber. Natural gas is available as an inexpensive fuel in many parts of the South. Accordingly, some of the operators, together with kiln engineers, started work on the development of direct gas-fired kilns, generally of a type which would serve the smaller operator who did not have steam available. The first stages of the movement were particularly directed at drying pine and air-dried hardwoods. Requirements here were not very exacting and very little trouble of a technical nature was experienced. The usual equipment and facilities for precision drying were not considered necessary. These conditions resulted in the development of rather inexpensive kilns designed for specific and limited needs. Recently some of the manufacturers have attempted to incorporate in their kilns all of the modern facilities and instruments for automatic heat and humidity control necessary for precision drying, but these improvements are still in the developmental stage.

The first commercial direct gas-fired kilns of which we have record were installed at the Kittrell Lumber Co., Tyler, Texas, in 1941, and the Fordyce Wood Products Co., Fordyce, Arkansas, in 1945. At the present time, approximately 150 companies in Texas, Arkansas, Louisiana, and Mississippi operate about 400 direct gas-fired kilns. The development of this particular field is expanding rapidly and the five firms manufacturing or assembling gas-fired kilns are making new installations daily. Fig. 1 shows the approximate location of the natural gas lines in our Station territory as well as the gas kiln installations that we have record of.

Types of Direct Gas-Fired Kilns

Basic features by which gas-fired kilns can be classified are the method of air circulation

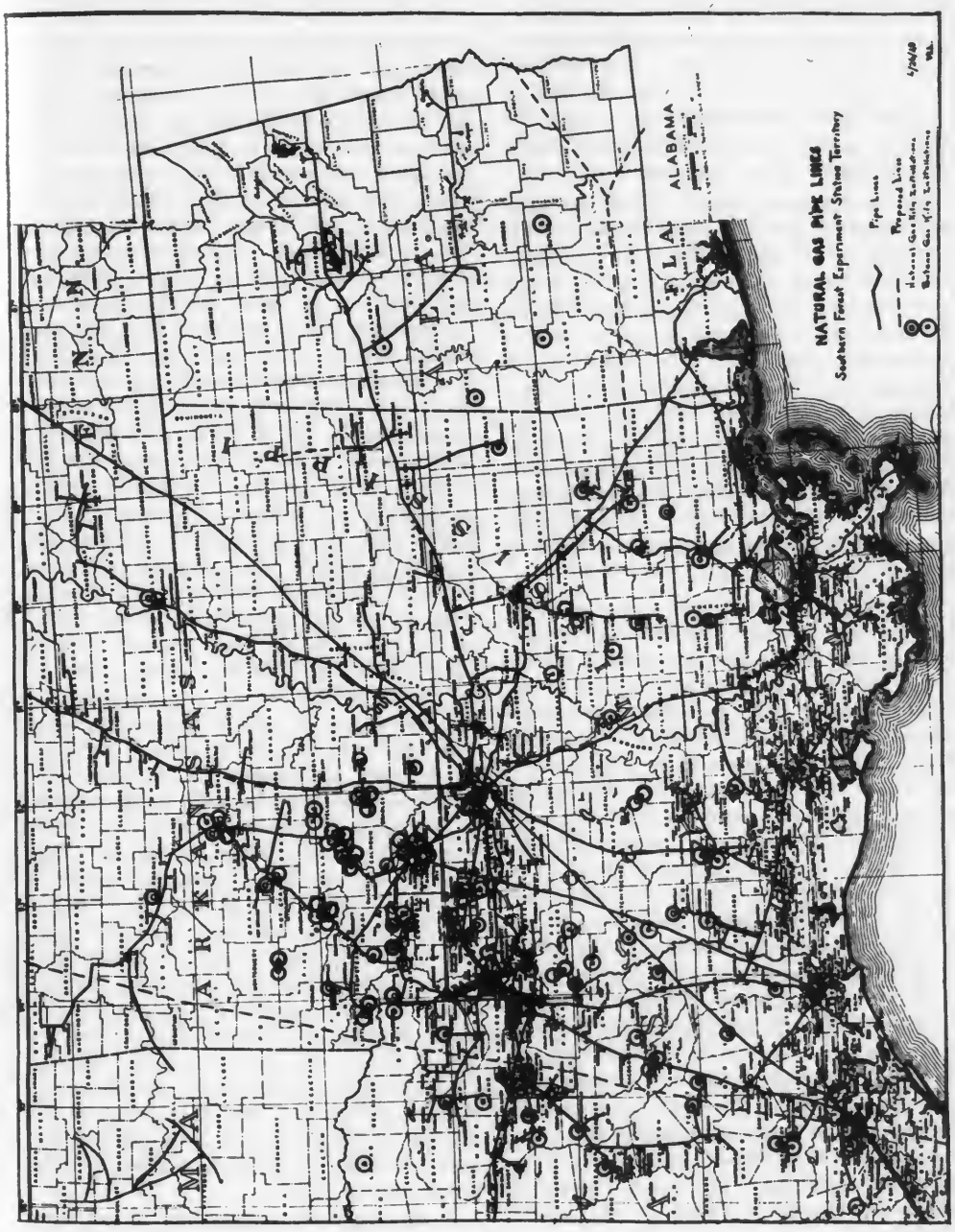

Fig. 1.—Natural gas pipe lines, Southern For. Expt. Sta. territory.

(either natural or forced draft), method of heat application (either manifold system, furnaces vented either inside or outside the kiln, furnace outside the kiln with a blower to force the products of combustion into the kiln, or open urn-type burners on gas lines inside the kilns), and method of humidity control (either steam, water sprays, or nothing).

The most common type is the natural draft with manifold heat. This type of kiln is manufactured by the Risser Dry Kiln Engineers, Inc., Little Rock, Arkansas. In this kiln the heat is furnished by a small gas furnace burner which opens into a manifold system located directly under the lumber. The manifold system leads into stacks that carry the products of combustion to the atmosphere. The kilns are made either as compartment or as progressive type. Humidity can be obtained by the use of auxiliary steam or water sprays, but these seldom are used. This type of kiln is most generally used for drying air-seasoned hardwoods but is also used for pine.

One of the more common types of direct gas-fired kilns is made by the Christopher Unitemp Heating System, Inc., of Prescott, Arkansas. In this kiln the heat is furnished by an external furnace with automatic temperature control. The heat is forced into a large duct which extends the length of the kiln between the cars of lumber. A number of openings at various intervals in the duct release the heat and products of combustion directly into the kiln. A large duct returns some of the warmed air from the kiln into a jacket over the furnace where it is reheated before being forced back into the kiln. Steam for humidity can be added by spraying water on the white hot fire brick inside the furnace at the entrance of the air duct, from where it is dispersed into the kiln. Reversible fans with vertical shafts furnish air circulation between the cars of lumber (the plane of rotation of the blades is parallel to the floor). This firm has recently added a system of baffles to give more direct control of air movement, and also a pressurized furnace in which the amount of intake air available is controlled.

The Lanly Company of Cleveland, Ohio, also manufacture direct gas-fired kilns of the blower type. Two kilns of this type are operating on pine in Alabama, but we have not checked on these installations.

Another rather common type of gas kiln is the forced draft model, manufactured by the Harry Russell Dry Kiln Co., Fordyce, Arkansas. Burners are of the urn type, vented inside the kiln and spaced at approximately 8-inch intervals along several headers. This arrangement gives control of heat throughout the length of the kiln. These burners are covered by a pyramid-shaped shield about 3 feet wide at the base and 6 feet high, and extends the full length of the kiln, between the cars of lumber. Openings in the top of this shield permit the products of combustion to enter directly into the kiln proper. Circulation of air is obtained by a system of fans, with vertical shafts, located over the shield and between the stacks of lumber. The fans are reversible so that the direction of air flow can be changed to help equalize drying conditions. No baffles are used to give better circulation between the courses of lumber. As in other types of gas kilns, humidity control can be obtained by the use of water sprays or auxiliary steam but these are seldom used. These kilns are more generally used as compartment-type kilns but they can also be used as progressive units.

A fourth type of gas-fired kiln is the forced draft, internally vented furnace-type manufactured by the Jack Russell Co., Fordyce, Ark. In this kiln the heat is supplied by gas furnaces at both ends of the kiln. Each furnace opens into a large metal combustion chamber which runs between the cars of lumber to the middle of the kiln. Short stacks or openings in the top of this combustion chamber release the products of combustion directly into the kiln proper. Dampers can be used on these stacks to control the temperature at the various locations within the kiln. A system of vertical reversible fans is located over the combustion chamber similar to the arrangement in the kiln previously described. In some cases impellers are attached to the fans located directly over the openings in the combustion chamber to draw the heat into the kiln.

A fifth type of gas-fired kiln is somewhat similar in principle to the fourth type in that it is a forced draft furnace type. It is manufactured by the Moore Dry Kiln Co., Jacksonville, Florida. The heating system differs from the

types just described in that the furnaces at each end of the kiln are underground and open into a metal combustion chamber located between low concrete retaining walls and extending the full length of the kiln between the cars of lumber. Vertical metal pipes 4 to 6 inches in diameter take off from the combustion chamber at various intervals and extend through the ceiling of the kilns. These pipes increase the size of the combustion chamber and provide additional radiating surface to heat the air being circulated within the kiln. The vertical pipes act as a booster coil in the center of the kiln to increase the temperature of the air after it has passed through one car of lumber and before it passes through the second. These vertical pipes are also used as dampered stacks to carry the products of combustion into the atmosphere. Humidity control is furnished either by water sprays or by auxiliary steam.

A system of large fans mounted on a central shaft, either below or above the cars of lumber, furnish the air circulation. The kilns are similar in many respects to the regular Moore steam kilns, and have the necessary baffles and air velocity to force the air through the lumber piles.

Operating Costs

Most of the direct-fired gas kilns are still in the development stage. Various features of design are being changed constantly to improve or correct deficiencies. This is an encouraging sign as the newly developed or improved features are usually incorporated in any new installations.

In an extensive survey of conditions, we have contacted some 50 direct gas-fired kiln operations in the last year. This reconnaissance gave us some generalized figures as to fuel consumption, quality and uniformity of drying, kiln limitations, etc., as well as a sound basis for developing more complete and detailed studies.

We have also made detailed studies of several operations using direct gas-fired kilns.

TABLE 1.—NATURAL DRAFT, MANIFOLD HEAT, COMPARTMENT TYPE KILN

Air Dried 4/4 Sap Gum Furniture Dimension. Drying time: 118 hrs.

Sample board No.	Sample code No.[1]	Air dry moisture content	Final moisture content	Sample code No.[1]	Final moisture content
		Percent	Percent		Percent
1	1-C	19.64	2.41	1-E	2.25
2	2-C	19.59	4.37	2-W	4.19
3	3-C	21.59	3.48	3-E	4.23
4	4-C	19.39	4.08	4-W	2.53
5	5-C	19.84	2.12	5-E	2.42
6	6-C	19.67	5.36	6-W	2.84
7	7-C	21.26	7.39	7-E	2.81
8	8-C	19.27	2.53	8-W	3.68
9	9-C	20.20	3.59	9-E	2.73
10	10-C	23.91	2.96	10-W	5.06
11	11-C	23.06	2.94	11-E	2.32
12	12-C	18.01	3.76	12-W	2.36
13	13-C	21.26	2.98	13-E	2.82
14	14-C	20.94	2.50	14-W	2.44
15	15-C	24.73	1.78	15-E	1.26
16	16-C	25.26	3.36	16-W	2.23
17	17-C	24.40	3.04	17-E	2.37
18	18-C	22.61	1.67	18-W	2.98
19	19-C	21.57	2.79	19-E	1.19
20	20-C	25.58	2.20	20-W	2.32
21	21-C	24.51	3.28	21-E	3.34
22	22-C	26.99	3.86	22-W	2.32
23	23-C	21.78	3.41	23-E	2.60
24	24-C	25.37	4.20	24-W	3.27
25	25-C	19.86	4.58	25-E	3.99
26	26-C	19.87	5.84	26-W	3.30
27	27-C	20.51	4.73	27-E	3.02
28	28-C	19.91	5.02	28-W	3.94
29	29-C	20.18	5.08	29-E	4.78
30	30-C	20.53	3.63	30-W	3.59
31	31-C	19.98	4.67	31-E	3.15
32	32-C	20.36	3.67	32-W	2.01
33	33-C	18.64	4.57	33-E	2.73
34	34-C	20.50	3.09	34-W	2.49
35	35-C	23.68	5.21	30-E	2.46
36	36-C	17.63	4.17	36-W	2.70

[1]16 ft. sample boards were cut into two 8-foot sections for matched samples.

TABLE 2.—NATURAL DRAFT, MANIFOLD HEAT, PROGRESSIVE TYPE KILN

Air Dried 4/4 Oak Flooring Stock. Drying time: 144 hrs.

Sample No.	Moisture content	
	In	Out
	Percent	Percent
1	14.8	6.5
2	14.8	6.5
3	13.8	6.0
4	16.8	6.3
5	— Lost	—
6	13.8	6.7
7	14.8	6.7
8	16.8	8.3
9	17.8	9.2
10	15.8	6.5
11	18.8	8.5
12	16.8	6.5
18	17.8	6.3
14	16.8	6.5
15	14.8	6.5
16	14.8	6.5
17	12.8	6.5
18	20.8	8.5
19	13.8	6.3
20	16.8	6.3
21	14.8	6.0
22	16.8	6.3
23	16.8	8.5
24	13.8	5.5
25	14.8	6.3
26	20.8	6.5
27	18.8	6.0
28	17.8	5.7
29	21.8	6.7
30	17.8	6.3
31	15.8	6.7
32	17.8	6.7
33	23.8	8.5
34	19.8	6.7
35	16.8	7.5
36	21.8	7.2
37	15.8	5.7
38	21.8	8.7
39	21.8	6.5
40	19.8	6.5
41	19.8	6.5
42	21.8	6.7
43	16.8	6.5
44	18.8	6.5
45	17.8	6.5
46	17.8	6.0
47	23.8	6.7
48	20.8	6.7
49	15.8	5.5
50	23.8	6.5
51	19.8	6.0
52	17.8	5.5
53	23.8	6.3

TABLE 3.—FORCED DRAFT, URN TYPE BURNERS, INTERNAL VENTED COMPARTMENT TYPE KILN

Air Dried 4/4 Oak Flooring Stock. Drying time: 144 hrs.

Sample board No.	Sample code No.[1]	Air-dry moisture content	Final moisture content
		Percent	Percent
1	1A1	32.3	[2]2.6
	1A10		8.9
2	1A1	32.8	3.8
	1A5		4.5
3	1A5	30.9	4.0
	1A10		2.6
4	1B1	36.9	3.6
	1B10		4.4
5	1B1	34.5	5.5
	1B5		5.7
6	1B5	29.5	4.0
	1B10		4.0
7	1C1	26.2	3.9
	1C10		4.9
8	1C1	32.1	4.2
	1C5		6.9
9	1C5	25.3	5.3
	1C10		2.6
37	3A1	46.7	[2]4.8
	3A10		6.3
38	3A1	40.0	6.0
	8A5		6.3
39	8A5	31.5	4.2
	3A10		4.1
40	3B1	28.3	4.0
	8B10		3.5
41	3B1	33.6	4.8
	3B5		6.6
42	8B5	32.9	3.6
	3B10		3.3
43	3C1	32.6	4.7
	3C10		4.9
44	3C1	36.0	4.5
	3C5		6.6
45	3C5	28.7	4.1
	8C10		4.2
46	5A1	27.3	4.0
	5A10		5.2
47	5A1	28.6	[2]5.0
	5A5		6.1
48	5A5	37.1	[2]9.8
	5A10		[2]6.9
49	5B1	28.8	2.3
	5B10		3.8
50	5B1	31.3	3.2
	5B5		4.9
51	5B5	33.1	3.7
	5B10		3.8
52	5C1	34.8	8.9
	5C10		5.8
53	5C1	31.4	3.5
	5C5		5.0
54	5C5	29.2	3.5
	5C10		4.2

All pieces severely case-hardened.

[1]16 ft. sample boards were cut into two 8-foot sections for matched samples.
[2]Honeycombed.

These studies were all made on the basis of the operating practices of the individual companies and are thus not a measure of the kiln capability alone, but of a combination of operating procedure and kiln capability. The partial results, however, shown in Tables 1, 2 and 3, give a good cross-section of the industrial use of gas-fired kilns.

Reported fuel costs varied from 25 cents to $2 per M bd. ft. of lumber dried. Most of the fuel costs, however, ranged between 50 cents and $1 per M bd. ft. when natural gas at from 15 cents to 25 cents per M cu. ft. of gas was used. In volume this is approximately from 2,000 to 5,000 cu. ft. of gas per M bd. ft. of lumber dried. The fuel costs varied largely by species and type of product, by size and type of kiln, and by differences in moisture content of lumber going into and out of the kilns. A detailed study of one of the progressive type natural draft kilns drying air-dried oak flooring stock indicated fuel costs of 65 cents per M bd. ft. during the winter months when the stock was heavy and 45 cents per M bd. ft. during the summer under more favorable conditions.

In addition to the inexpensive fuel one of the chief advantages of direct gas-fired kilns is the reduced operating costs. The use of automatic thermostat temperature control requires only a few minutes time per day of the kiln operator, plant manager, or watchman to maintain desired temperatures night and day. This eliminates the need of round-the-clock firing and boiler tending.

Reported drying time ranged from 48 hrs. for well air-dried oak to 160 hrs. for heavier and wetter material. Pine green from the saw, 4/4 stock, usually required from 72 to 120 hrs. This, of course, varied with kiln efficiency and with the moisture content of the wood going into and out of the kilns.

Temperature Control and Other Problems

Dry bulb temperatures of 180° to 220° F. with no moisture control were most commonly used for green southern pine. There was in general no apparent degrade from using this schedule. For air-seasoned oak initial temperatures usually ranged from 130° to 150° F. increasing to around 180° to 200° F. as rapidly as possible and maintaining that for the full period. Such high temperatures with no added humidity usually caused considerable honeycombing damage in lumber that exceeded 30 percent moisture content when it went into the kiln. For lumber of less than 30 percent moisture content, the damage to flooring stock was negligible.

Most of the gas kilns add no moisture during the drying process nor do they have control of the humidity. Some kilns, however, are equipped with water or steam sprays, which give some measure of humidity control, and these kilns apparently have no difficulty in producing a product that meets the acceptable specifications.

We do not know of any gas-fired kilns that have ample control of the humidity to equalize or condition lumber as recommended by the Forest Products Laboratory. At the present time this is not considered very important or essential by some of the manufacturers of gas-fired kilns. If they were seriously interested they could remedy this problem without too much difficulty.

Only a few limited studies of moisture content of lumber from gas-fired kilns were made. These indicated that while some firms were able to get satisfactory results, others were having serious difficulty. Some of the difficulty can be charged to the limitations of the kiln and some to improper operation. Where the requirements were not too exacting, the kilns were in general considered satisfactory for air-dried hardwoods or for green pine.

It is of interest to note that direct gas-fired kilns are being used for flooring stock, furniture dimension, construction lumber, handle stock, and various other products.

The attached tables give detailed information regarding the uniformity of moisture content of 4/4 air-dried hardwoods going into and coming out of various types of gas-fired kilns. Sample boards were systematically placed so as to check uniformity throughout the length of the kiln, across the load, and vertically in the pile.

Sections were cut from each sample following the drying periods and checked for degree of stress. With very few exceptions, all samples showed from light to serious case hardening or stressed condition. For these products,

flooring stock and furniture dimension, which were not to be resawn into thinner products, case hardening was not considered detrimental and no degrade or allowance was made for it.

We have not gone into the question of fire hazard or insurance for direct gas-fired kilns, but it is evidently a very serious problem. A number of kilns have been destroyed by fire and in some States the rates are so high that insurance is considered prohibitive. In some instances, however, and for some operations, very satisfactory insurance rates are obtained.

The kiln manufacturers are attempting to reduce fire hazard to a minimum. Most of the trouble from fire seems to result from either carelessness or faulty design, and it should not be difficult to correct these items.

Discussion

R. A. Cockrell (University of California): Are steps being taken to make the humidity control more precise?

Mr. Lehrbas: Yes. Some firms are taking steps to improve the humidity control problem.

Prof. Cockrell: Is the prevailing view that the direct gas-fired kiln is innately more susceptible to fire justified on the basis of your observations in the South?

Mr. Lehrbas: Yes. There is naturally more danger from fire from direct-fired kilns than from steam kilns where the source of fire may be several hundred feet from the kiln.

In those kilns where the products of combustion are dumped into the kiln proper, there is also danger of fire from the accumulation of unburned gas in the kiln, due to incomplete combustion.

Richard H. Elliott (Standard Dry Kiln Co.): Is there any chance of getting low insurance rates on new kilns?

Mr. Lehrbas: We have not gone into the fire insurance question for direct gas-fired kilns. This seems to vary, however, by insurance company and by states. The insurance companies can probably furnish this information.

A. C. Knauss (U. S. Forest Service): The subject of low-capital-cost dry kilns is of great interest to the lumber producers of the Pacific Northwest. This area has many small mills cutting Douglas fir which sell and produce green lumber because their operation does not justify the capital investment required for permanent fire-proof dry kiln equipment and steam power plant in general use.

Attempts have been made to construct low-capital-cost driers, arranged to be heated with "wood waste" which is available at the plant without cost. Efforts to develop satisfactory equipment of this kind have not been too successful. This is due partly to the relatively high fire risk. Recently one of the leading insurance companies has stated that their experience with fires has been so disastrous in wood, oil, or gas-fired kilns which do not use steam as a heating medium that the company is restricting writing dry kiln insurance to those heated by steam.

Another effort to produce a kiln for the small mill operator has been directed toward the fabrication of aluminum wall and ceiling panels which are laid onto a steel building frame. These panels are insulated against heat loss and provide a warm, light kiln building, enabling a small heating plant to provide the heat required to operate the kiln. One additional feature of this construction is that the building consequently is also highly vapor tight and the steam and other heating requirements of the kiln are relatively low.

Quality Control and Seasoning

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Statistical methods are a valuable aid in establishing and maintaining desired seasoning standards in woodworking plants, it has been demonstrated by the Forest Products Laboratory in tests at two furniture plants. Standards of seasoning quality—that is, uniformly low moisture content—were arrived at and adhered to in regular production at both plants by establishing a desired average moisture content and acceptable standard of deviation, called the uniformity factor. The statistical data needed to establish and maintain the desired average and uniformity were obtained at one plant by sampling lumber as it arrived from the kilns in the fabricating shop and determining the moisture content of the samples by the oven-drying method; at the other plant the samples were tested with electric moisture meters. Stock of unacceptable seasoning quality as indicated by these standards indicated a need for remedying some step in the drying process.

Introduction

THE purpose of this paper is to stress the importance of defining the degree of seasoning quality needed in woodworking plants, in order to minimize waste due to moisture content changes during fabrication and increase assurance that the products will not develop faults in subsequent use attributable to excessive moisture change. Once moisture content standards are established for fabrication purposes with wood, management can use the relatively new technique of statistical quality control to see that these standards are attained.[2]

Moisture Content Standards for Wood Fabrication

The seasoning of wood has as its most important objective the reduction of its moisture content to a point that will cause it to remain approximately stable during the manufacturing process in actual use. Many other advantages and benefits are gained from the use of dry wood, regardless of whether the drying process used is air drying, kiln drying, a combination of both, or some special process such as chemical pretreatment followed by air drying or kiln drying or such processes as solvent drying or vapor drying.

Moisture content standards for wood at the time it is used to fabricate consumer products can be determined in different ways: (1) by analyzing the equilibrium moisture content conditions that will prevail in the many different environments of use; (2) by measuring the moisture content of wood in actual use; (3) by surveying the opinions and attitudes of people familiar with the products, their manufacture and use, and (4) by testing the moisture content of wood being fabricated and, depending upon the extent and nature of the complaints of customers, determining the moisture content necessary at the time of manufacture.

The Forest Products Laboratory has published recommendations regarding the moisture content of wood most suitable at the time of installation for different uses.[3] These recommendations are based on surveys of the moisture content of wood in service and are given in Table 1. They are generalized for interior

[1] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[2] The mathematical aspects of statistical quality control and control charts are not described in this paper. A number of texts are available which deal with this branch of statistical methods.

[3] U. S. Forest Products Laboratory Wood Handbook. Supt. of Documents, Government Printing Office, Washington, D. C.

TABLE 1.—RECOMMENDED MOISTURE-CONTENT VALUES FOR VARIOUS WOOD ITEMS AT TIME OF INSTALLATION

Use of lumber	Moisture content (percentage of weight of oven-dry wood) for					
	Dry Southwestern States		Damp southern coastal States		Remainder of the United States	
	Average	Individual pieces	Average	Individual pieces	Average	Individual pieces
	Percent	Percent	Percent	Percent	Percent	Percent
Interior finish woodwork and softwood flooring	6	4–9	11	8–13	8	5–10
Hardwood flooring	6	5–8	10	9–12	7	6–9
Siding, exterior trim, sheathing, and framing	9	7–12	12	9–14	12	9–14

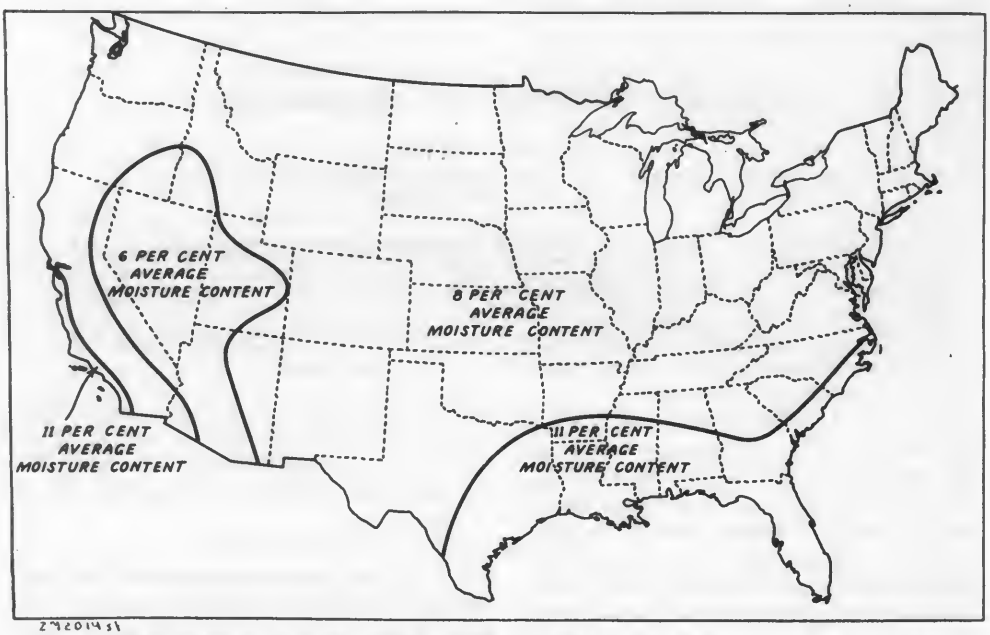

Fig. 1.—Recommended moisture content averages for interior finish woodwork for use in various parts of the United States.

finish woodwork, which can very well include furniture, in graphical form in Figure 1. These recommendations have been very helpful to the woodworking industry as they give management a good basis upon which to guide seasoning operations.

It is general commercial practice to dry some wood products, such as flooring and furniture wood, to a lower moisture content than service conditions demand, counting on a moderate increase in moisture content during storage and manufacturing. This is done to reduce losses due to checking and warp caused by moisture content changes during fabrication. When factories are heated in the winter, for example, further drying of the cut-up and semifinished pieces is caused that often results in serious losses due to checking and splitting, whereas during the summer months swelling of excessively dried wood results in warp and splitting of panels. Moisture content standards for factory control purposes must be adjusted to reduce these losses, yet stay within the limits indicated by surveys of moisture content in use. Further, the seasoning quality goals indicated by such surveys must be qualified to provide indications of allowable variations at the time of fabrication or installation that will result in satisfactory service. Industrial experience has generally confirmed the recommendations for the average moisture content values given in Table 1, with modifications to control fabrication losses.

Seasoning quality control, however, is concerned not only with the average but also with the allowable tolerance in moisture content. The suggested range in moisture content of individual pieces given in Table 1 does not provide a suitable standard of "allowable variation" for adequate statistical control of the fabrication process. It is, of course, manifestly impossible to test all pieces of wood going through a fabricating plant for moisture content. Yet inspectors must have some reliable and reasonably cheap method of ascertaining whether a suitable range is being maintained, so that the expenditures to reduce factory losses and increase consumer satisfaction are not greater than the costs resulting from such losses or complaints.

Experiments have shown that standards can be established for seasoning control on the

basis of considering wood moisture content as a variable and expressing the objectives of seasoning in terms of (1) the average and (2) the standard deviation. Data such as given in Table 1 provide recommendations for the average, which management can modify as experience dictates. The tolerance factor, or the standard deviation associated with the average, cannot be so readily set up from the data in Table 1 or from management experiences, as this quality characteristic has not been determined. Another term for the standard deviation is "uniformity factor," which is used at the Forest Products Laboratory because it has a more direct word association with the actual work done.

The uniformity factor for furniture production discussed in this paper is based on tests of the wood being fabricated. It is realized that other approaches may be made to establish economic values of this variability characteristic. For example, a direct approach to the establishment of moisture content standards for a flooring mill would be to lay a number of floors having similar exposure conditions at different average moisture content values and different uniformity factors associated with each average variable; after a number of years of use, the opinions and attitudes of people called in to examine the floors would be surveyed and, thereby, standards set for future production. This survey of customer opinion has many advantages. Unfortunately, however, such a research program would be extremely costly for any one wood product. At present, therefore, an indirect approach is being used by the Forest Products Laboratory to learn the value for average moisture content and the uniformity factor desired for wood being made into furniture on the basis that, if the manufacturer is satisfied that the fabrication losses due to moisture change during processing and consumer complaints are not excessive, these two values can be the basis of standards for future operation and control.

Statistical Quality Control

Before presenting the results of the Forest Products Laboratory's studies of moisture content control in the furniture industry and recommendations based on them, the applicable features of statistical quality control are considered.

Statistical quality control makes use of two statistical techniques, the control chart and statistical sampling. Moisture content standards or specifications for wood are expressed in terms of the average moisture content and the uniformity factor. Statistical sampling provides the moisture content data, and with the control-chart method they are analyzed with respect to control.

Control Chart

The control chart has been developed in various forms. Essentially, however, it is a device for plotting data, such as the moisture content of wood, in such a way that the frequency and extent of variation from standards are immediately revealed. Control limits based upon the established tolerance limits (the uniformity factor) are drawn upon the chart. Variations in the average moisture content or uniformity factor that fall within the control limits may be considered as arising from the natural variability of a material or a process. Variations that fall outside the control limits are danger signals and indicate that there is a definite, assignable cause at work helping to bring about the variations. The control chart tells the manager at a glance whether the process of seasoning, for example, is in control. When non-control is indicated, action may be required to determine the assignable cause.

The primary value of control charts is that they tell the manager and the supervisor of the seasoning operation when assignable causes for variation are at work. They contribute an additional advantage, however, in that they publicize seasoning results; thus, they furnish a convenient way of stimulating improved seasoning performance.

Statistical Sampling

The second technique involved in statistical quality control is sampling. It is a process of taking random tests of the material being processed. In seasoning control work, this means sampling the wood for moisture content, and the number of tests to be made, how they are made, and where and when they are taken become very important phases of statistical quality control. The moisture content sample, for

example, must be taken in such a way that a true picture of the whole operation is obtained, with equal chance that both wet and dry boards will be in the sample. The size of the sample—that is, the number of moisture content tests taken per kiln truck per kiln charge, per day of factory operation or any other satisfactory unit—will usually be determined, at least to begin with, by the method selected for moisture determination and the man hours allotted to the work. A number of moisture content sampling schemes can be worked out, depending upon the needs of the situation. In each instance, however, the sampling method must assure freedom from bias in selecting the specimens to be tested for moisture content.

Experiments in Quality Control

To demonstrate the applicability of statistical quality-control techniques to control the moisture content of rough lumber being fabricated into furniture, two experiments are reported. Just prior to World War II, an experiment was started at a furniture plant in Sheboygan, Wis. Sufficient data were collected to establish moisture standards and show that the control-chart method of interpreting the performance of the dry kiln was reasonably efficient. An experiment now in progress at a furniture plant in Thomasville, N. C., confirms the moisture standards indicated by the first study and, further, shows the suitability of electric moisture meters for the moisture inspection process.

Sheboygan Test Results

The Sheboygan tests were designed (1) to determine the average moisture content of kiln-dried hardwood lumber being processed into furniture; (2) to determine the uniformity factor of lumber being fabricated; and (3) by means of moisture standards based on preliminary data, to check future dry-kiln performance with control charts and a small moisture content sampling of the stock being cut up in the machine room.

The preliminary data from which the final moisture content specification was evolved were collected by obtaining about 40 moisture content sections per day over a period of 188 days. The sampling process at the cut-up saw was completely random, and no specific instructions were given to the saw operator other than that the specimens should not be cut from portions of the boards less than 2 feet from the ends. The kiln-dried boards were rough dressed at this plant before being cut, so that the moisture sampling represents the moisture condition after the first machining operation. The saw operator cut out a section for moisture content analysis about every 10 or 15 minutes, so that the total number was collected over the day's machine room operation. The sections were placed in a closed container, and three or four times daily the dry-kiln operator picked them up, weighed them, and finally bundled the day's sampling for shipment to the Forest Products Laboratory for oven drying and calculation of moisture content. The collected data are plotted in Fig. 2.

The collection of preliminary data was started in the spring and was discontinued in December. The average moisture content drifted towards higher values in the summer months. The analysis of these data by the control-chart method is shown in Fig. 3. The average moisture content for the whole period was 5.6 percent and the uniformity factor was 1.0. In most instances, the cause for lack of control of the uniformity factor could be ascertained. The cause of the lack of control indicated by the deviations of the average below and above the limits for the average could not always be determined, although one of the general causes was the gradual change in moisture content of the kiln-dried wood from the spring period of factory heating to the summer period of an "open" plant.

All during the collection of preliminary data the furniture produced was marked or coded in such a manner that future troubles could be traced back to the moisture content condition of the stock used. As yet no complaints on this furniture have been registered with the company, and, therefore, it is reasonable to conclude that the average moisture content and uniformity factor based on the preliminary data represent a good moisture content specification for this firm's products.

The average moisture content of stock going into production was lower than recommended in Table 1, the difference being the reduction in moisture content needed to control fabrication problems. The new information provided

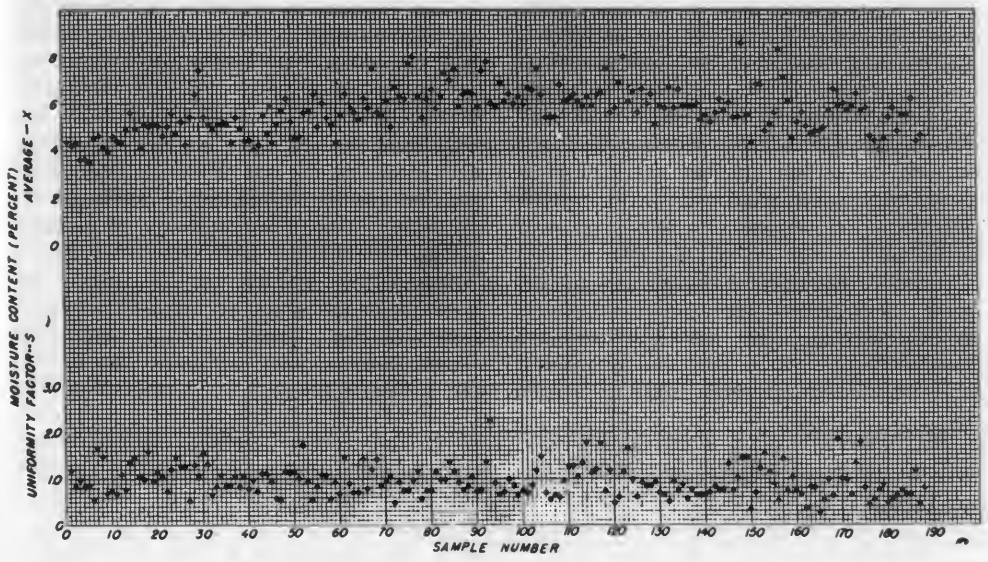

Fig. 2.—Average moisture content and uniformity factor of lumber going into furniture production at a Sheboygan, Wis., plant. Data are based on a sample size of approximately 40. These preliminary data were collected from March 18 to December 10.

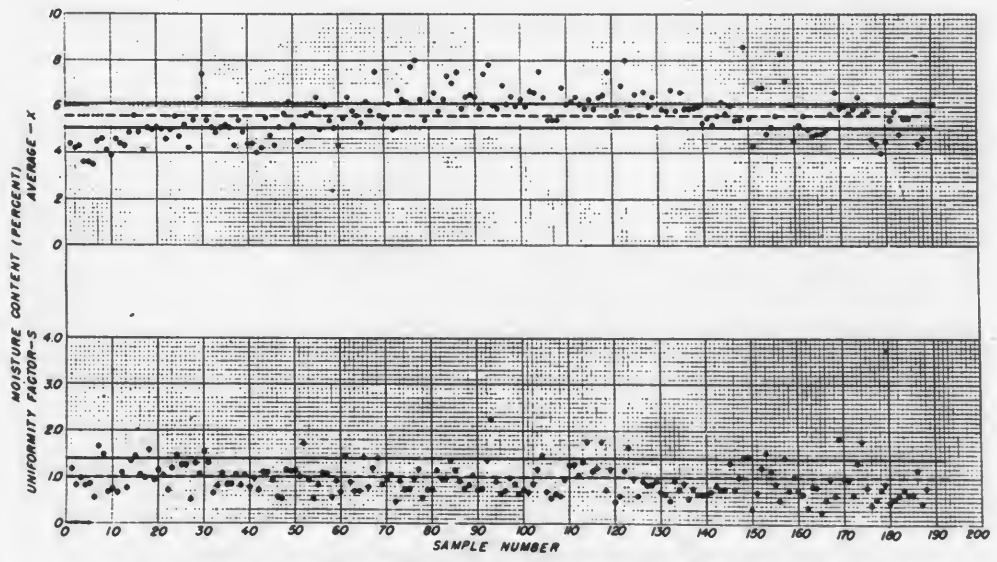

Fig. 3.—Control chart for analysis of the preliminary Sheboygan data shown in Fig. 2.

n = approximately 40
$\bar{X}$ = 5.6 percent
S = 1.0

The control limit for the average is 5.1 and 6.1 percent. The upper control limit for the uniformity factor is 1.4.

by this study was the uniformity factor of 1.0. It was decided by the company to use the average moisture content of 5.6 percent and the uniformity factor of 1.0 as moisture content standards for future production. To run moisture content tests on 40 oven-dry sections a day was out of the question, and for experimental purposes a sample size of 10 was decided upon for statistical quality control of seasoning.

A control chart was drawn up and the control limits calculated. The study was continued for 152 working days, data for which are shown in Fig. 4. At no time did the uniformity factor exceed the upper limit of 1.6 for this quality characteristic. Control of the average moisture content was not so well in hand. It appears that it was more difficult to control the average moisture content than it was to get uniformity of moisture content.

The experiment yielded a set of moisture content standards by which to measure seasoning performance at a furniture factory. The average moisture content value of 5.6 percent and a uniformity factor of 1.0 constitute specific seasoning standards. Whether other furniture producers can use these standards is dependent upon factory operating conditions. The sampling scheme involving only 10 moisture content sections and oven drying is also subject to further factory test. The sample size seems much too small, yet the data of Fig. 4 show significant seasonal trends and actual situations where the close control desired was not being attained.

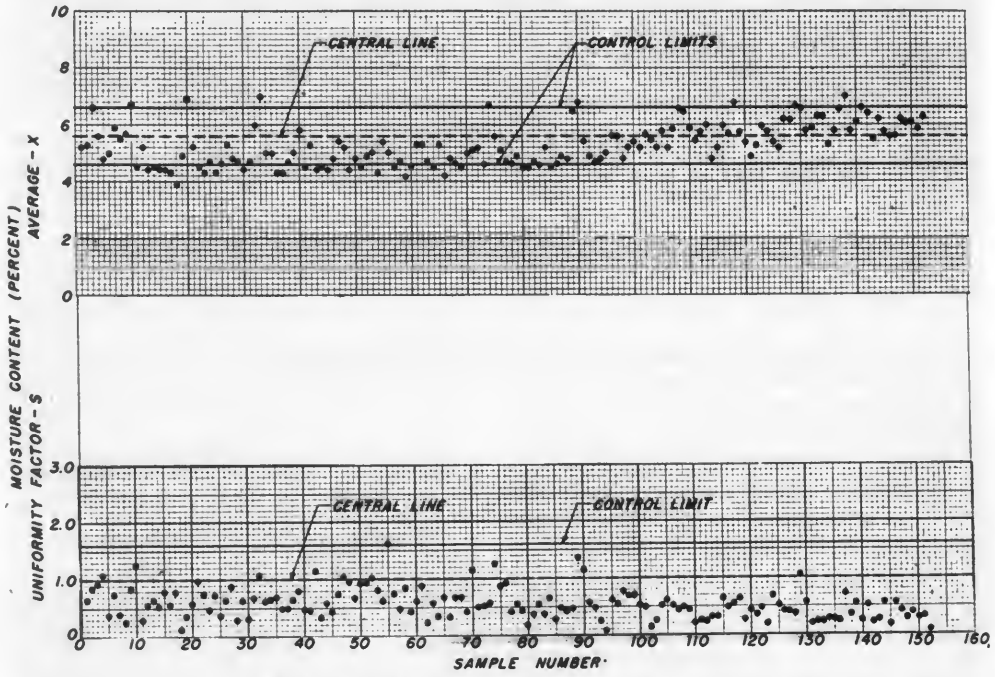

Fig. 4.—Control chart for daily sampling at Sheboygan.

$n = 10$
$\bar{X} = 5.6$ percent
$S = 1.0$

Control limit for average is 4.6 and 6.6 percent. Upper control limit for uniformity factor is 1.6.

Thomasville Test Results

The study at Thomasville, N. C., was recently initiated (1) to obtain additional information on moisture specifications for furniture production; (2) to determine whether the

electrical moisture meter can be used as an inspection tool for quality control work; and (3) to determine whether the inspection costs and control chart methods are worthwhile.

Although the moisture content standards for furniture production obtained at Sheboygan might well apply to other furniture manufacturing industries, at least for initial trial purposes, it was decided to obtain preliminary information on seasoning quality before setting up specific statistical quality control charts. Moisture content data were collected, as at Sheboygan, on rough-dressed stock. Instead of cutting moisture content sections, however, the specimens were taken from the conveyor belt, checked for moisture content with an electric moisture meter, and then thrown back on the belt for further processing. A resistance-type moisture meter was used for the preliminary studies and is still being used for the quality control work, which will continue as long as management believes the information is worth the cost of getting it. The meter being used has as its lowest direct moisture reading a value of 6.0 percent, but estimates of moisture content of 5.5 and 5.0 percent are made. All wood specimens indicating a value of less than 5.0 are classed as 5.0 percent because there is no way of telling how much lower they are.

The preliminary data taken with the electric moisture meter can be quite comprehensive because they can be rapidly determined. One man was able to obtain 50 readings representing one kiln truck of lumber with little difficulty. The preliminary data obtained are plotted in Fig. 5. Each point represents 50 mois-

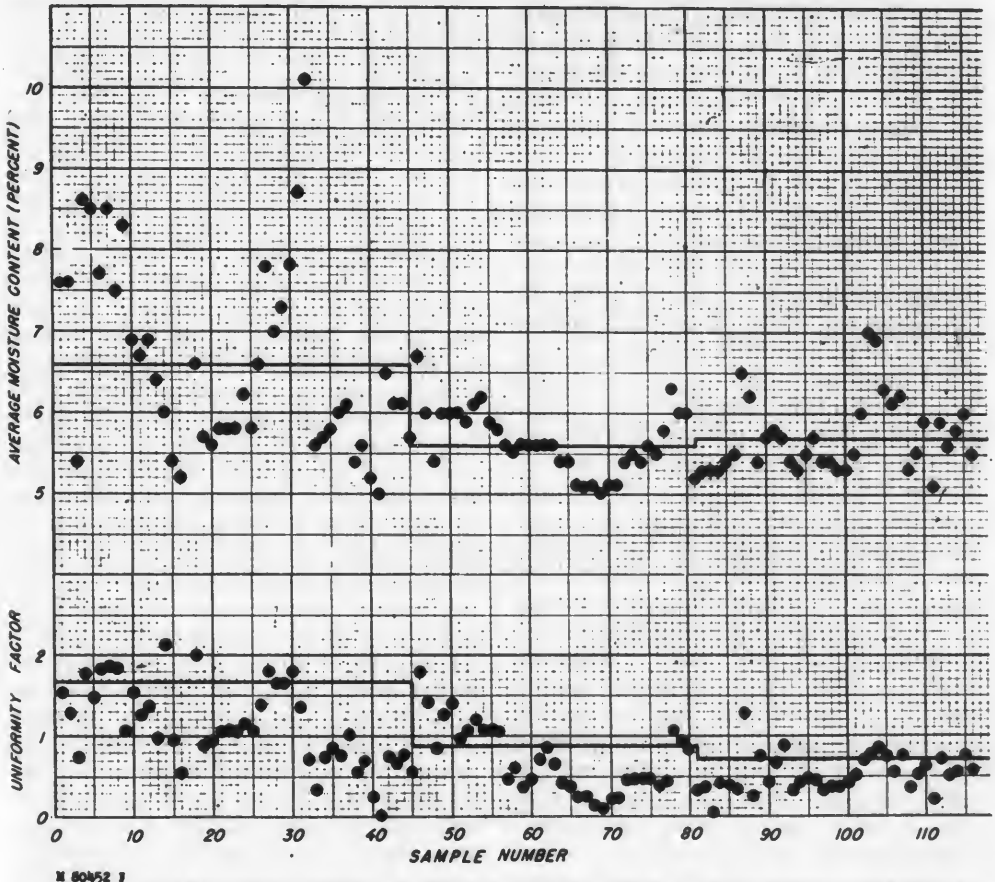

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Fig. 5.—Average moisture content and uniformity factor of lumber going into furniture production at a Thomasville, N. C., plant. Data are based on a sample size of 50 taken with an electric moisture meter. These preliminary data were collected from August 10 to October 7.

ture content readings, or tests, from one kiln truck of lumber. Six or seven kiln trucks of lumber were being processed per day on the line in the factory on which these tests were made.

One of the outstanding advantages of quality control is illustrated by the data shown in Fig. 5. Initially both the average moisture content value and the uniformity factor floundered around, indicating that moisture content was not being controlled from one kiln truck to the next. Different kiln charges seemed to be the influential factor, both as to the average and the uniformity factor. As the inspection continued, the quality of drying improved. Inspection for the moisture content of stock resulted in greater effort on the part of the operator to send uniformly dried stock to the machine room. The data being collected enabled him to do this, as they provided him with evidence on which to base kiln operational methods—telling him whether adjustment of drying schedules or increased time in the kiln was needed to improve the drying results.

Studies of this kind do not penalize kiln operators, and therefore statistical quality control is of as much interest to the kiln operator as to management, the control charts telling management what is happening and whether the operator is getting desired kiln performance. Such data can even be used to convince management that "firing operators" isn't always the answer to lack of control—that more is expected of the equipment than it can do even with good supervision, and that repair or modification is in order.

The data of Fig. 5 show the steady improvement in drying results. Sample Nos. 81 to 116 showed an average moisture content of 5.7 percent and a uniformity factor of 0.73. This result checked the moisture content standards at Sheboygan remarkably closely. When the 116th sample was taken the weather was such that the factory was being heated occasionally, and it was decided to establish 5. as the standard for the average moisture content and 0.75 for the uniformity factor for future performance. A control chart was drawn up based on a sample size of 25 tests per day.

The control-chart record for 68 working days is shown in Fig. 6. With the moisture standards established and the sample size for statistical quality control decided, the control limits for the average were calculated as 5.0 and 6.0 percent. When the average moisture content of the daily sample of 25 tests falls between these limits for the average, the stock that was sampled is under statistical control and the kiln operator has complied with one moisture content standard. The upper limit of the uniformity factor is 1.04, and if the uniformity factor for the day's sampling is less than this value, the second requirement of quality control is attained.

The method adopted of obtaining the 25 samples from the day's operation in the machine room may be of interest. It would be expensive to maintain an inspector in the machine room to pick up these few moisture tests. Therefore, the wood specimens, after being rough dressed and cut to length, are randomly selected by a rip-saw operator and piled on a truck. His instructions are to set aside 25 or more samples a day, selecting four or more samples from every kiln truck, the specimens to come from different layers in the kiln truck as it is taken down at the cut-off saw. Next morning the inspector randomly selects 25 from the lot set aside by the rip-saw operator for moisture content analysis. After being tested with the moisture meter, the specimens are put back into production. The inspector picks up the tickets taken from the kiln trucks, which provide the information regarding the kiln in which the stock was dried, the location of the trucks in the kiln, the date the charge was pulled, and the thickness, grade, and species being tested. A typical data sheet is shown in Fig. 7. The average moisture content and the uniformity factor are calculated as shown. The uniformity factor is the square root of the mean square minus the square of the mean.

Five factories at the cooperating plant in Thomasville, N. C., are being checked for statistical quality control, all operating with the same moisture content standards. A control chart is set up in each dry-kiln operator's office and the moisture content inspector posts the results of the moisture tests every morning. The work takes about one-half of a man's time. Each week the supervisor of each factory is given a summary report of the past week's moisture control results.

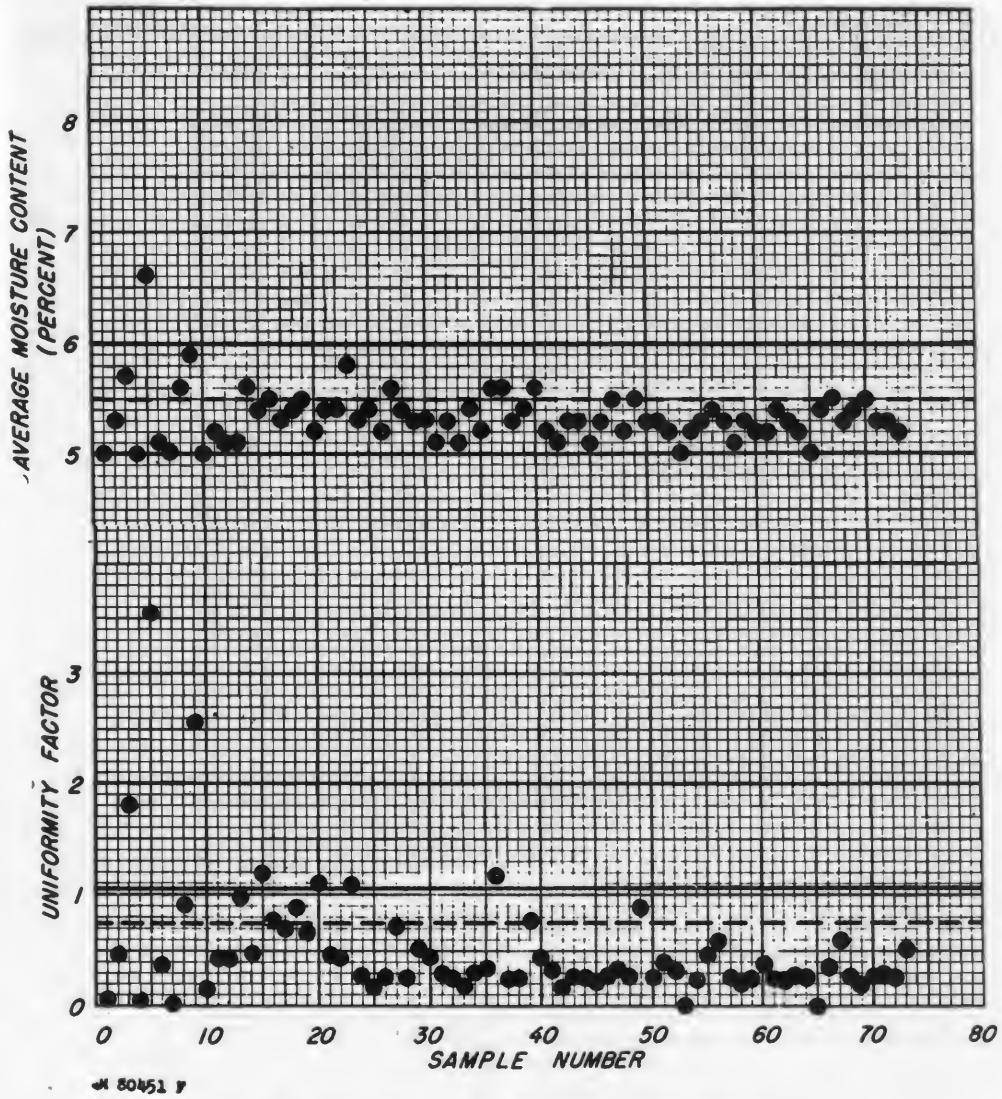

Fig. 6.—Control chart for daily sampling at Thomasville, N. C.

$n = 25$
$\bar{X} = 5.5$ percent
$S = 0.75$

Control limit for average is 5.0 and 6.0 percent. Upper control limit for uniformity factor is 1.04.

"C"

MOISTURE CONTENT OF STOCK GOING INTO PRODUCTION

DATE Nov 16, 1948 SAMPLE NO. 28

ITEM NO.	DRY KILN NO.	KILN TRUCK NO.	DATE OUT OF KILN	THICK-NESS	GRADE	SPECIES		METER READING	M.C. (%)	(M.C.)²
1	10	1	11/9	4/4	1com	Pt Gum		5.5		30.25
2								5.5		30.25
3								5.5		30.25
4								5.5		30.25
5	"	2	"	"	"	"		5.5		30.25
6								5.5		30.25
7								5.5		30.25
8								5.5		30.25
9	"	3	"	"	"	"		5.5		30.25
10								5.5		30.25
11								5.5		30.25
12								5.5		30.25
13	1	2	11/10	4/4	"	"		6.0		36.00
14								5.0		25.00
15								5.0		25.00
16								5.5		30.25
17	11	4	11/12	4/4	"	"		5.0		25.00
18								5.5		30.25
19								5.5		30.25
20								5.5		30.25
21	"	5	"	"	"	"		5.0		25.00
22								5.5		30.25
23								6.0		36.00
24	"	6	"	"	"	"		5.5		30.25
25								5.0		25.00
26										
27										
28										
29										
30										
31										
32										
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38										
39										
40										
41										
42										
43										
44										
45										
46										
47										
48										
49										
50										
TOTAL								134.0		744.50
MEAN								5.48		29.66

29.6600
29.5936
.0664

F 80524 F

UF = .26

Fig. 7.—Typical data sheet showing results of moisture content tests with electric meter at Thomasville, N. C., plant.

Evaluation of Test Results

Moisture Standards for Furniture Production

Although the average moisture content values at Sheboygan were running less than 5.5 percent during the winter heating season, this value seems to be working out reasonably well at Thomasville. No specific troubles were observed that were due to moisture content changes during fabrication. Thus, pending a check on customer complaints at Thomasville, this value for the average seems reasonably good as a moisture content standard, particularly for the period of the year when the factories are heated. Although the value of 5.6 percent seemed to be satisfactory at Sheboygan for summer operation as well, it has been decided to raise the standard to about 6.5 percent for "open factory" conditions at Thomasville next summer.

The uniformity factor was 1.0 at Sheboygan and 0.75 at Thomasville. As the moisture meter readings do not reflect the moisture content range where some of the stock has less than 5.0 percent, the apparently better performance at Thomasville is really not a true picture. It is believed, on the basis of results at both plants, that a uniformity factor of 0.75 is a good standard to set up as a goal regardless of whether moisture content is tested with a meter or by the oven-drying method, particularly where forced air circulation dry kilns are available.

When moisture content specifications for wood being processed are established in terms of average moisture content and a uniformity factor, statistical evidence of adherence can be obtained by sampling for moisture content and interpreting the data by means of quality control charts. The data reported here are based on two different moisture content sampling techniques. Woodworking industries interested in this method of moisture content control can, of course, develop other techniques more suitable and less costly than these. From the standpoint of statistical sampling, the use of electrical moisture meters will greatly reduce the costs involved. The use of these meters in connection with quality control techniques needs considerable applied research, and such investigations will pay off in reduced costs.

The control chart is a graphical method of analyzing data. Dry-kiln operators and plant managers can understand what it shows. Whether they will be used by the woodworking industry along with moisture standards based on factory experiences and customer environment remains to be seen.

Conclusions

Quality control methods making use of statistical sampling schemes and the control-chart method of interpretation are applicable to the seasoning of wood. Moisture content standards developed from Forest Products Laboratory recommendations for moisture content in use, modified to meet factory processing needs and surveys of present performance, can be used as goals for future operation. By putting the seasoning process under observation, the losses and costs involved in getting wood properly dried will be brought to the attention of management. Moisture content control in wood-fabricating industries is important and, by specifying standards and using quality control methods, the weaknesses of the air-drying, kiln-drying, and storage processes can be brought to light and changes introduced to improve seasoning results.

The results of these experiments in seasoning quality control indicate that rather definite moisture content standards can be specified for kiln drying rough lumber for furniture fabrication. These standards are 5.5 or 5.6 percent for the average and 0.75 for the uniformity factor for winter periods of operation when the factories are heated. It is believed a higher average moisture content should be set as a standard for the summer periods when the factories are not heated.

These moisture content standards for furniture fabrication are expressed in terms that can be constantly checked for adherence. Statistical quality control methods using the control chart and statistical sampling apply.

Discussion

E. Sigurd Johnson (Salem, Virginia): Mr. Rietz, your method of using uniformity factor is technically correct and is of value to a manager but I believe it is confusing to the average plant man. Why can't you set up a specific

average moisture content plus high and low limits in moisture content for individual tests. If more than a specified number of tests per day or per week fall outside the control limits, then corrective steps are called for in kiln operation. Wouldn't such a procedure of using actual moisture content control limits be more understandable and practical to use in a woodworking plant?

Mr. Rietz: I had hoped that the term "uniformity factor" instead of the standard deviation would aid the average plant man in understanding what this quality characteristic means. The idea is to show that although the stock may be dried to the right average moisture content, it doesn't necessarily mean that it is dried sufficiently uniform to make a good product. Statistically I question the advisability of setting up limits for one or two samples. I'd much rather try working with sample sizes of 5 to 10 and setting up the range within which the moisture values must fall to show adherence to the moisture specifications. I believe this system would be quite adaptable where stock is being checked to determine whether it should or should not be used.

Richard H. Elliott (Standard Dry Kiln Company): Why not control before drying in kilns?

Mr. Rietz: The question here pertains to the most economic and expedient place to obtain the desired uniformity of dryness; in the dry kiln or in a dry lumber storage shed equipped with devices to control wood E. M. C. I am of the opinion that the dry kiln is the place where uniformity of dryness can be obtained with the least expense. Modern forced air circulation dry kilns with instrumentation to control temperature and relative humidity accurately can be operated to produce uniformly dried stock. On the other hand, few dry storage sheds are equipped with fans which would be needed to obtain the desired uniformity, even though wood E. M. C. control is provided by heating.

Woodrow W. King (Texas A & M College): Recently the Texas Dry Kiln Club sponsored a Kiln-Tune-Up Project in the East Texas pine belt. Mr. W. Karl Loughborough, formerly of Forest Products Laboratory at Madison, was employed for the project. His findings indicated the woeful incapacity of many of the kilns surveyed to perform a job of seasoning uniformity. Isn't it rather imperative, therefore, that, before quality control can be imposed, much needs to be done to improve kiln performance?

Mr. Rietz: Kiln performance will only be improved when information is obtained showing poor performance. The statistical quality control approach measures kiln performance and if the quality is poor, action programs are indicated. Therefore, I believe quality control procedures are a part of a kiln performance improvement program. It demonstrates that the actions taken are producing results.

W. I. West (Oregon State College): Another problem in this regard is connected with proper moisture control from the manufacturer to the final installation. Quite often this results in dissatisfaction by the user which is incorrectly blamed against the manufacturer.

For example: Western white and ponderosa pine paneling has been shipped to Willamette Valley retailers (Oregon). Due to storage malpractices the material picked up moisture to the extent that shrinkage occurred after being put into use, resulting in large cracks between boards and often warping.

It appears that some thought might be given to quality control in retail yards, furniture storage and even during shipping of quality items. This would contribute to a more satisfactory performance of wood products and go far towards customer appeal.

Mr. Rietz: I am in complete agreement with this idea. The first step is to provide a practical system of moisture standards for the producer. A system is needed which both the lumber producer and lumber buyer can agree on and I believe the statistical quality control method overcomes some of the difficulties encountered with previous systems of moisture specifications. When the retailer is assured of moisture quality he will be interested in maintaining that quality and passing it on to his customers.

FOREST PRODUCTS RESEARCH SOCIETY

Further Observations on Longitudinal Shrinkage of Softwoods

Robert A. Cockrell

Associate Professor of Forestry, School of Forestry, University of California, Berkeley, California

Further information on the longitudinal shrinkage of ponderosa pine and new data on the longitudinal shrinkage of six additional softwoods are reported. The data corroborate previous findings on ponderosa pine. Summerwood strips elongate slightly in drying from the green to the air-dry condition, but decrease in length with continued drying to the oven-dry condition. Springwood strips normally shorten slightly in drying from the green to the air-dry condition and shorten appreciably on drying to the oven-dry condition. Measurements on blocks with different widths of growth rings indicate that wide growth rings or rapid growth is not the cause of excessive longitudinal shrinkage in the softwoods studied.

PREVIOUSLY *(1, 2, 3)*, the writer reported on the longitudinal shrinkage of ponderosa pine *(Pinus ponderosa)* wood blocks and separate summerwood and springwood strips, and using these data along with the findings of Koehler *(5)* and Welch *(8)*, made certain general statements regarding the fundamental nature of longitudinal shrinkage. The data presented in this paper from wood of white fir *(Abies concolor)*, shortleaf pine *(Pinus echinata)*, longleaf pine *(P. palustris)*, Monterey pine *(P. radiata)*, loblolly pine *(P. taeda)* and Douglas-fir *(Pseudotsuga taxifolia)*, in addition to ponderosa pine, confirm the previous findings and make possible more general conclusions regarding the shrinkage of softwoods.

Procedure

Material for the western species was obtained from log disks 9 inches thick sawn from both ends of butt logs of freshly cut trees. The shrinkage blocks cut to dimensions of about ¾ inch square cross section with rings approximately parallel to one edge and six inches in length were selected more or less at random in the disks, but care was exercised to avoid any abnormalities such as proximity to pith, grain irregularities or compression wood. These blocks were first roughed out by splitting in order to insure straightness of grain, and then the surfaces were smoothed to facilitate numbering and measuring. The shrinkage blocks of the three southern pines were cut from sections of green slabs supplied by the Wood Technology Department of the New York State College of Forestry. A piece of wood ⅛ inch thick was sawn from the best radial face of each block and carefully separated into summerwood and springwood splints. The blocks and the splints, held rigid in an adjustable jig, were measured in a bench gauge with a dial micrometer reading to 0.001 inch to obtain length values successively for the green, air-dry (approximately 11 percent moisture content), and oven-dry conditions. The average percentage changes in length, based on the original green length, in drying to the air-dry and oven-dry conditions were computed for each type of specimen and are presented in Table 1. Values representing elongation on drying are preceded by a minus sign in order to be consistent with the earlier studies already referred to.

Incidental to the foregoing aspect of the study, since springwood splints often arced in drying, several of the springwood splints obtained from wide growth rings were separated into an outer portion and an inner portion that were measured separately. The shrinkage data for these specimens are recorded in Table 2.

Results and Discussion

The data in Table 1 for the percentage change in length of summerwood in drying from the green to the air-dry condition indicate that for the seven species considered, it is normal for a slight elongation to take place. In 1931 Koehler *(5)* reported similar results for summerwood of southern yellow pine, Douglas-fir, and redwood. Further drying to the oven-dry condition results in a decrease in length from that existing at the air-dry condition, and usually the wood becomes shorter

TABLE 1.—LONGITUDINAL SHRINKAGE OF WOOD BLOCKS AND CORRESPONDING SUMMERWOOD AND SPRINGWOOD STRIPS

Tree[1] Sample No.	Block Shrinkage				Summerwood Shrinkage				Springwood Shrinkage				
	No. of blocks	G.—A.D.[2] Av. ±	G.—A.D.[2] St. Dev.	G.—O.D.[2] Av. ±	G.—O.D.[2] St. Dev.	No. of rings	G.—A.D.[2] Av. ±	G.—A.D.[2] St. Dev.	G.—O.D.[2] Av. ±	G.—O.D.[2] St. Dev.	No. of rings	G.—A.D.[2] Av. ±	G.—A.D.[2] St. Dev.	G.—O.D.[2] Av. ±	G.—O.D.[2] St. Dev.
		Percent	Percent	Percent	Percent		Percent	Percent	Percent	Percent		Percent	Percent	Percent	Percent
9A	3	—0.12[3]	0.02[3]	—0.01	0.02	11	—0.27	0.05	—0.16	0.06	11	0.22	0.06	0.41	0.06
13A	3	— .12	.03	— .03	.03	16	— .23	.06	— .13	.06	15	.11	.06	.26	.06
14A	2	.02	.03	.10	.03	20	— .01	.04	.10	.04	18	.12	.03	.22	.04
46A[4]	1	.02	----	.18	----	5	— .19	.07	— .09	.10	5	.07	.03	.30	.06
50A	3	— .01	.03	.15	.03	12	— .05	.03	.07	.03	12	.08	.02	.25	.03
50B[4]	4	.03	.00	.17	.01	20	— .01	.02	.12	.03	20	.06	.02	.22	.03
53A	12	— .01	.03	.07	.04	35	— .04	.04	.05	.06	35	.12	.07	.26	.09
53B	9	.03	.02	.11	.02	24	— .02	.01	.11	.02	26	.04	.02	.20	.05
54A	6	— .01	.02	.06	.05	16	— .05	.04	.06	.06	14	.07	.05	.22	.05
54B	14	.02	.01	.13	.02	43	— .01	.02	.11	.02	44	.04	.03	.19	.03
55A	5	— .01	.01	.07	.03	15	— .03	.02	.08	.02	15	.01	.02	.13	.03
55B	7	.02	.02	.12	.03	23	— .03	.02	.09	.03	18	.02	.02	.16	.02
56A	13	— .01	.02	.07	.04	31	— .04	.03	.07	.04	29	.01	.03	.13	.04
56B	11	.01	.02	.11	.03	28	— .02	.04	.11	.04	28	.01	.03	.15	.02
57A	2	— .01	.01	.15	.03	5	— .03	.01	.10	.06	6	.03	.04	.17	.09
58B	3	.03	.02	.20	.05	7	— .03	.01	.16	.02	8	.01	.03	.16	.04

[1]Species legend: 9, longleaf pine; 13, loblolly pine; 14, shortleaf pine; 46 and 50, ponderosa pine; 53 and 54, Douglas-fir; 55 and 56, white fir; 57 and 58, Monterey pine.
[2]G.—A.D. means green to air-dry moisture content (about 11 percent) while G.—O.D. means green to oven-dry moisture content.
[3]Both averages and standard deviation values are expressed in hundredths of percent. Negative values represent elongation.
[4]Designation A indicates material was obtained near base of tree, while B indicates that it was obtained at about 18 feet up the tree.

TABLE 2.—LONGITUDINAL SHRINKAGE OF SUMMERWOOD AND INNER AND OUTER SPRINGWOOD FROM IDENTICAL GROWTH RINGS

Tree Sample No.	Rings from pith	Ring width	Green to Air-dry			Green to Oven-dry		
			Summer wood	Inner spring wood	Outer spring wood	Summer wood	Inner spring wood	Outer spring wood
		Inches	Percent	Percent	Percent	Percent	Percent	Percent
53A[1]	60	0.25	—0.03[2]	0.07	0.26	0.08	0.20	0.46
53A	40	.29	— .02	.03	.23	.05	.12	.35
53A	18	.42	— .21	.00	.25	— .18	.07	.43
53B	11	.30	— .03	.00	.05	.07	.13	.22
55A	56	.38	— .05	— .05	.00	.03	.03	.12
55B	8	.20	— .03	.02	.03	.10	.15	.15
57A	28	.43	— .02	— .03	.00	.17	.08	.15
58B	18	.60	— .05	— .02	.00	.20	.13	.17
58B	6	.40	— .03	.03	.08	.17	.12	.28
58B	19	.54	— .02	— .02	.03	.15	.15	.22

[1]See legend in Table 1, footnote [1].
[2]Negative values indicate elongation on drying.

than in the green condition. Judging from the rather consistent difference between the A and B samples in Table 1, the summerwood near the base of the tree has a greater tendency toward elongation than that at the higher levels. Thus there is greater elongation at the air-dry condition, and, as a result, the net shortening is less at the oven-dry condition for summerwood from this location.

Referring now to the data for springwood in Table 1, it may be observed that springwood usually shortens slightly in drying to the air-dry condition, although, in a few instances, slight elongation of specimens takes place. Examination of the original data disclosed that several springwood specimens from six of the tree samples elongated slightly and some specimens from three others showed no change in length for this stage of drying. In drying to the oven-dry condition, the springwood of most of the samples shortened appreciably. Three-fourths of the tree samples failed to show proportionality between moisture content change and shrinkage. Unlike the summerwood, proximity to the base of the tree does not appear to have any effect on the springwood shrinkage.

The pattern of wood block length change with drying, revealed by the data in Table 1, as would be expected, is the result of the combined effect of the summerwood and springwood, and, quantitatively, is more or less intermediate between these two types of wood. Material from near the base of a tree usually exhibits a slight elongation at the air-dry condition and a definite shortening at the oven-dry condition. That from above the base of the tree ordinarily shortens no more than a few hundredths of a percent at the air-dry stage and up to two tenths of a percent at the oven-dry stage. In this connection, it is pertinent to refer to a statement of Hermann and Rasmussen *(4)*, "Broadly speaking, the longitudinal shrinkage of the pines from green to oven-dried is of the order of 1/10 of 1 percent. It is somewhat freakish in its nature, since a board at 14 to 16 percent moisture content may be a trifle longer than it is when green, but, if the drying is continued below these moisture content figures, loss of dimension is experienced." From the data presented here, it can be concluded that slight elongation of a fair number of specimens at the intermediate moisture contents in drying (16 to 10 percent) is in no sense freakish but is to be expected as the normal situation.

Wide growth rings resulting from rapid growth do not ordinarily exhibit excessive longitudinal shrinkage. Many of the blocks from tree samples 50, 53, 55, 57, and 58 that were included in computations for Table 1 had growth rates of two to three rings per inch. One block of Monterey pine (tree sample 58B) with rings averaging two-thirds of an inch in width had shrinkage to the air-dry condition of 0.02 percent and 0.25 percent to the oven-dry condition, which is quite typical of wide rings when they are not from near the pith and lack compression wood. The data presented in Table 2 can also be referred to as evidence of the normal shrinkage behavior of rapidly grown wood. When appreciable longitudinal shrinkage of softwoods does occur it can ordinarily be attributed to compression wood (mild or pronounced), proximity to pith, or irregu-

larities of grain. Although other workers *(6, 7)* have ascribed excessive longitudinal shrinkage to rapid growth, it is the writer's opinion that the reports of their work do not establish this fact. Most of the wide-ringed material they refer to appears to come from near the pith of second-growth trees, and therefore cannot be referred to as typical of rapid growth in general.

Examination of the data in Table 2 reveals the fact that changes of length of the inner portion of the springwood with change in moisture content resemble somewhat the changes that take place in the summerwood. The outer portion of the springwood, on the other hand, has, in almost every instance, appreciably greater shrinkage than the summerwood. Comparing this with the data in Table 1, it would appear that the shrinkage of the entire springwood of the growth ring is influenced more by the outer than by the inner portion.

Summary

Summarizing the foregoing discussion, the following general statements can be made about longitudinal shrinkage of clear, straight-grained softwood free from compression wood and at least six rings from the pith, based on the seven species considered in this study:

1. Summerwood normally elongates slightly in drying from the green to the air-dry condition, but decreases in length with continued drying to the oven-dry condition.

2. Summerwood near the base of a tree elongates more than that higher in the tree in drying to the air-dry condition.

3. Springwood normally shortens slightly in drying from the green to the air-dry condition, but shortens appreciably with continued drying to the oven-dry condition.

4. Softwoods, on the average, do not change in length more than a few hundredths of a percent in drying to the air-dry condition but are shortened from 0.1 to 0.2 percent at the oven-dry condition.

5. Rapid growth *per se* is not a cause of excessive longitudinal shrinkage of softwoods.

6. The outer (first formed) portion of the springwood has appreciably greater shrinkage than the inner (later formed) portion.

Literature Cited

(1) Cockrell, R. A. 1943. *Some observations on density and shrinkage of ponderosa pine wood.* Trans. A.S.M.E. 65:729–739.

(2) —— 1946. *Influence of fibril angle on longitudinal shrinkage of ponderosa pine wood.* Jour. Forestry 44:876–878.

(3) —— 1947. *Explanation of longitudinal shrinkage of wood based on interconnected chain-molecule concept of cell-wall structure.* Trans. A.S.M.E. 69:931–935.

(4) Hermann, Albert, and C. A. Rasmussen. 1935. *Shrinking and swelling of ponderosa pine.* West. Pine Assoc. Tech. Bul. 1, 14 pp. illus.

(5) Koehler, A. 1931. *Longitudinal shrinkage of wood.* Trans. A.S.M.E. W.I.D. 53: 17–20.

(6) —— and R. F. Luxford. 1931. *The longitudinal shrinkage of redwood.* Timberman 32:32, 46, 48.

(7) —— 1938. *Rapid growth hazards usefulness of southern pine.* Jour. Forestry 36:153–158.

(8) Welch, M. B. 1935. *The longitudinal variation of timber during seasoning.* Part II. Jour. and Proc. Royal Soc. New South Wales. 68:249–254.

Discussion

F. F. Wangaard (Yale University): Professor Cockrell's conclusion that excessive longitudinal shrinkage is not related to rate of growth as such alters somewhat a concept that has been rather generally accepted. Perhaps one comment may help to clarify some difficulties that seem to arise in connection with his conclusion. I take it that he does not interpret his results as contradicting the relationship that has been so commonly observed in young conifers. In such material a rapid rate of growth *near the pith* is usually associated with abnormal longitudinal shrinkage.

Prof. Cockrell: That is essentially correct. Excessive longitudinal shrinkage seems to be more a function of proximity to pith rather than rate of growth. Since most conifers have wide rings more commonly near the pith than further out in the log cross section, it is not strange that there has come about this associa-

tion of high longitudinal shrinkage with rapid growth.

Roy M. Carter (North Carolina State College): Is the change from air-dry to oven-dry condition always accompanied by an increase in length?

Prof. Cockrell: No. It is usually accompanied by a slight decrease in length for normal wood. Wood from near the stump occasionally still shows elongation when dried to the oven-dry state. Most of the elongation, however, occurs in drying to the air-dry state, and I think we could conclude that summerwood usually increases in length at this stage of drying. This effect is largely offset by the springwood shrinking, however, so the net effect is often zero or slight shrinkage.

Prof. Carter: During the war, when precision in aircraft fabrication dimensions was essential, the question of changes in length frequently occurred. This information and similar data on other species throws some light on the cause for these changes.

Measurements were taken on blocks ¾ inches square and 6 inches long. Does this elongation of longleaf and loblolly pine in drying from green to air dry or 11 percent moisture content actually take place in commercial lumber sizes?

Prof. Cockrell: Measurements of full-sized boards were not made although I believe it can be assumed that boards allowed to dry in an unrestrained condition would show similar elongation.

FOREST PRODUCTS RESEARCH SOCIETY

Development of Collapse in Aspen Lumber[1]

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Division of Forestry, University of Minnesota

Collapse of the wood in an intermediate zone between sapwood and heartwood is a serious defect developing in aspen lumber during kiln-drying, particularly when rapid or severe kiln schedules are used. The intermediate zone, often called "wetwood", which is so subject to collapse has a very high moisture content when compared to heartwood and sapwood; it is heavily infected with bacteria; it is very impervious to the passage of air and water; and both the "wetwood" and heartwood are weaker than the sapwood in certain strength properties. "Wetwood" zones are readily detected in logs and green lumber and losses from collapse can be reduced by sorting and separate drying, either air drying or kiln drying with mild schedule, of boards containing such wood.

Introduction

THE production of aspen lumber in the Lake States has grown from an almost insignificant amount twenty-five years ago to 152,000,000 board feet in 1946.[2] Production of lumber from this former weed species in Minnesota alone was 68,000,000 board feet in 1946. Because of the large area of aspen in the Lake States, growth at present greatly exceeds drain and this excess of growth over drain is expected to increase unless utilization for present uses can be greatly increased and new outlets can be developed.

According to Zasada[2] aspen lumber in 1945 was used for the following purposes: 80 million bd. ft. or 75 percent for boxes and crating, 15 million bd. ft. or 14 percent for building purposes, 8 million bd. ft. or 8 percent for core stock, 2 million bd. ft. or 1.5 percent for furniture, and 2 million bd. ft. for novelties, woodenware, venetian blinds, etc. Recent efforts have been directed towards increasing the utilization of aspen lumber for such higher value products as core stock, furniture, building material, and venetian blinds, etc.

Major problems faced in attempts to increase the utilization of aspen lumber are the short lengths and narrow widths of boards produced, the presence of natural and seasoning defects, generally inferior manufacture by small mills, prejudice and lack of knowledge of the characteristics of the species, and general unavailability of a graded or standardized product that can be marketed in competition with material from other regions.

Some of the problems faced in efforts to increase the markets for aspen are relatively insolvable—for example the narrow widths and short lengths of boards, because of the inherent nature of the species. Other problems, such as the development of standard grades, improved manufacture, dissemination of information regarding the characteristics of the species, and reduction in the amount of defect developing during seasoning are capable of solution and require attention if this species is to gain the position in the lumber field that its availability and general properties indicate that it deserves.

One of the important defects developing in aspen lumber during seasoning, particularly during kiln drying, is collapse. Collapse of lumber during kiln drying has received considerable study in case of many commercially important lumber species, particular attention being given to preventive measures, but little or no study of this defect has been made in case of aspen. This paper is a preliminary report of a study made to determine the extent or occurrence of collapse in aspen lumber during air seasoning and kiln drying, the location of collapsed areas within boards, the detection of material that may collapse while still in log form, the characteristics of the wood in those zones most affected by this defect (Fig. 1), and possible means of prevention.

Occurrence and Importance of Collapse

Collapse in air-seasoned aspen lumber is not serious and causes relatively little defect. The general observation made on air-seasoned lumber at a number of northern Minnesota saw-

[1] This study was partly financed with funds provided under the Research and Marketing Act of 1946.

[2] Zasada, Z. A. Aspen properties and uses. Lake States Aspen Report No. 1. Lake States Forest Experiment Station. 1947.

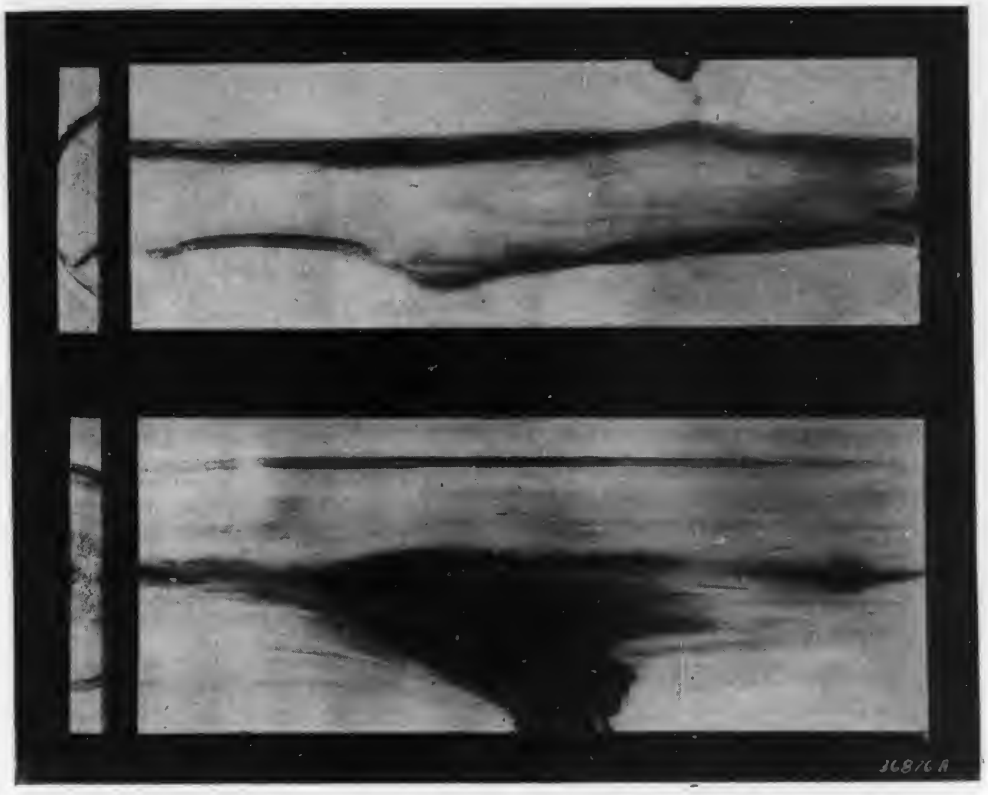

Fig. 1.—Surface and cross-sectional views of two aspen boards containing "wetwood". Photographed in the green condition.

mills, which was corroborated by the opinion of mill operators, indicates that less than 5 percent of the boards are affected. Furthermore, collapse developing during air-seasoning is never as serious as during kiln-drying and the defect is largely eliminated in planing.

In case of aspen kiln-dried from the green condition, the occurrence and severity of collapse was found to be almost directly correlated with the kiln schedule. In a box-lumber mill where green lumber was dried to a moisture content of 12 to 18 percent in 72 hours, serious collapse was found to occur in 58 percent of the boards in a random sample of about 1,000 board feet of 4/4 lumber tallied. Of the boards containing collapse, 60 percent were estimated to contain collapse that would not plane out and which would need to be resawed into thinner stock or otherwise utilized to recover a portion of their value. In a second plant, manufacturing furniture core stock, a much milder kiln schedule was used in drying from the green condition to a moisture content of 5 to 7 percent and the frequency and severity of collapse was found to lie between that for air-seasoned lumber and the box lumber dried under rather drastic conditions.

These observations corroborated the findings of Smith,[3] that while the occurrence and severity of collapse in aspen lumber is closely correlated with drying conditions, it can and does occur to a limited extent even under relatively mild kiln-drying schedules and during air seasoning. Its greater occurrence in kiln-drying is no doubt due to a considerable extent to the

[3] Smith, H. H. Seasoning of aspen. Lake States Aspen Report No. 5. Lake States Forest Experiment Station. 1947.

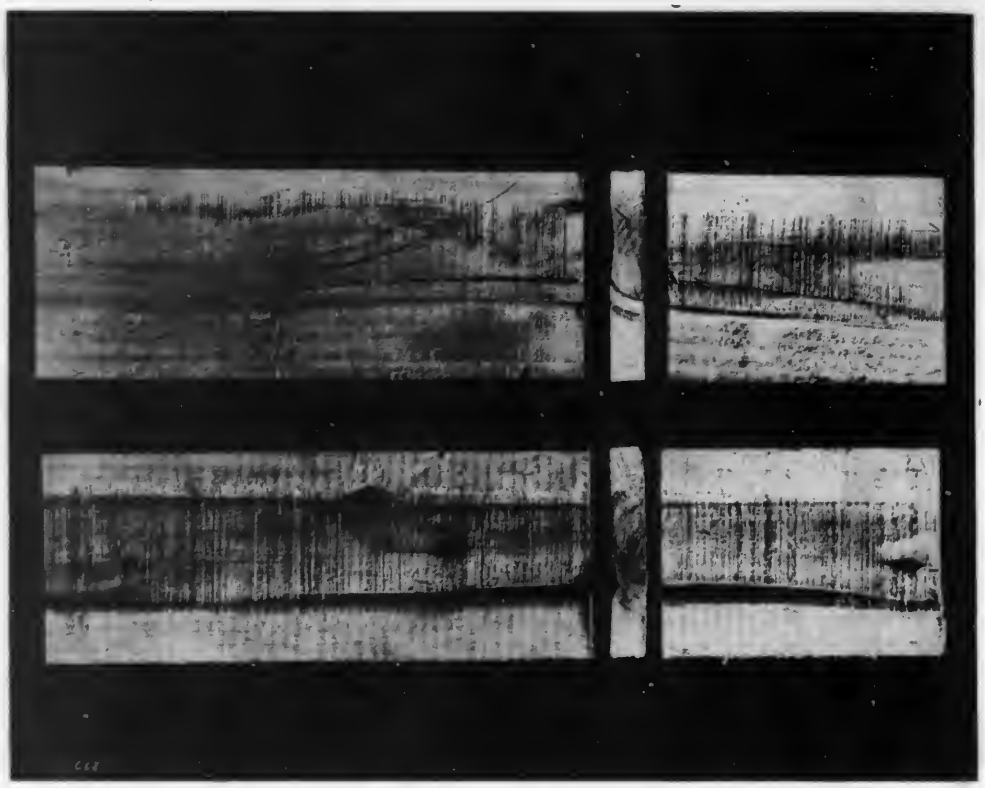

Fig. 2.—Surface and cross-sectional views, after planing, of two aspen boards which collapsed seriously in the "wetwood" zone during kiln drying.

plasticizing effect of heat on the cell walls and a resultant decrease in resistance to collapse as well as to the severity of drying conditions.

The importance of collapse is directly correlated with the use made of the lumber. When used for boxes and other containers only the most severe collapse results in waste and loss. The loss may consist of rejection of short cuttings or only of portions of cuttings in case the material is resawed. In case of furniture core stock and building lumber, however, even mild collapse may result in rejection of entire boards or considerable loss in cuttings because the material does not plane smooth. The development of shake (Fig. 2) in connection with severe collapse may result in added losses in grade and volume.

The Location of Collapse in Boards

Collapse in aspen has never been found to occur in sapwood, which fortunately makes up the greater portion of most aspen logs (Figs. 3 and 4). Consequently, the drying of flat-sawn all-sapwood boards is not a problem and drying without the development of collapse can be accomplished even under rather drastic drying conditions. The wood most subject to collapse consists of a rather narrow band lying between the heartwood and sapwood and occasionally certain spots in the heartwood. This intermediate zone or band of wood, lying between the heartwood and sapwood commonly called "wetwood"[4] can usually be recognized because of its darker color and wet appearance (Figs. 1 and 3). It does not occur in all aspen logs and may not be uniformly distributed in individual trees or even in individual logs. In addition to the collapse developing in these bands of wetwood, there is an occasional development of

[4] Hartley, C. and Crandall, B. S. Vascular diseases in poplar and willow. (Abst.) Phytopath. 25 (1): 18–9.

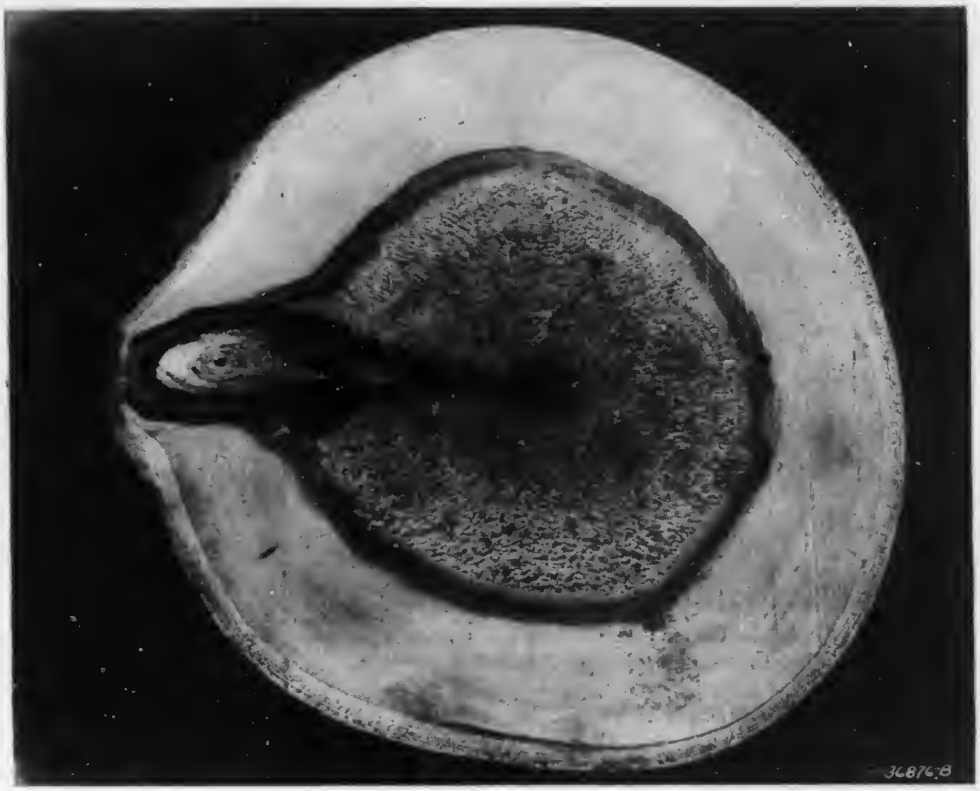

Fig. 3.—Cross-section of an aspen log showing the distinct "wetwood" zone between heartwood and sapwood. In spite of the appearance of the heartwood, no evidence of wood rotters was found in the isolations made from the log. The roughness of the cut is believed to be due to the lower strength and somewhat lower moisture content of the heartwood.

this defect in the dark-colored wood so characteristic around knots and other defects.

That it is possible to detect, from the appearance of the ends of logs, material that may collapse on drying was shown by sampling a large number of logs during the course of this study and drying this material in the laboratory. Only infrequently did boards cut from logs showing typical "wetwood" zones on the ends fail to develop some collapse when dried in the laboratory under conditions comparable to those encountered in kiln-drying schedules in use at box lumber plants.

The Characteristics of "Wetwood" Zones

In an attempt to determine why collapse is largely limited to the zone of wood between heartwood and sapwood (Figs. 1 to 4), a study was made of the characteristics of this wood and how it differed from heartwood and sapwood which are generally quite free from this defect.

Moisture Content

The appearance of the wood in the zone between heartwood and sapwood is indicative of a high moisture content. That the moisture content of this zone is actually higher than that of the heartwood and sapwood has been shown by Pillow.[5] In a sample of 16 aspen boards showing "wetwood" zones, Pillow found the average moisture contents of the sapwood, "wetwood" zone, and heartwood to be 100.5, 127.2, and 107.0 percent respectively, and the

[5] Pillow, M. Y. Unpublished Forest Products Laboratory manuscript.

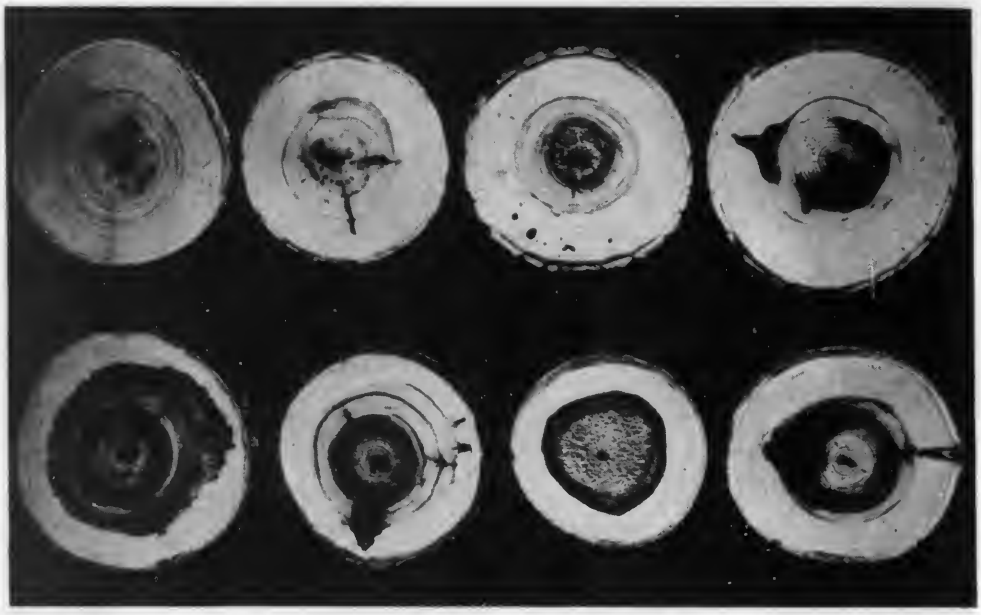

Fig. 4.—Cross-section of eight different aspen logs showing variations in pattern of the "wetwood" and heartwood regions.

"wetwood" zone of one board had a moisture content of 228 percent. In a study of 8 aspen logs by the writers, moisture contents for the sapwood, "wetwood" zone, and heartwood were found to be 91.3, 113.4, and 80.1 percent respectively. In another sample of 8 logs, the moisture content was found less consistent but the moisture content gradient between zones was very abrupt. These results would indicate that the so-called "wetwood" zones of aspen logs are correctly named and that this wood normally has a considerably higher moisture content than adjacent heartwood and sapwood.

Imperviousness

The commonly accepted explanation for collapse in lumber is that the water within the cell cavity moves out of the cell as a column and exerts a cohesive force on the cell walls strong enough to pull the walls of the cell together. For this to occur, the cells must be filled with water and the wood must be relatively impervious to the entrance of air. The importance of imperviousness as a contributing factor in the development of collapse is indicated by the rarity of collapse in sapwood, which may have very high moisture contents in aspen as well as in most woods but which rarely shows collapse even under drastic drying conditions.

To test the imperviousness of material from the "wetwood" zone of aspen logs and compare this with sapwood and heartwood, the "soap bubble" test described by Tiemann[6] was made. Thin cross sections of wood cut from these three zones of aspen logs showed that the "wetwood" and heartwood sections were practically impervious to the passage of air whereas the sapwood was quite pervious. The imperviousness of aspen heartwood and "wetwood" to the penetration of liquids has been frequently demonstrated in attempts to treat posts, ties, and lumber of this species with wood preservatives. Even under conditions of high vacuum and pressure little or no penetration of preservatives is obtained in the "wetwood" and heartwood. Also, there is some evidence to indicate that the erratic or spotty penetration of preservatives in aspen sapwood is due to the occurrence of developed or incipient impervious "wetwood" areas scattered through the sapwood.

[6] Tiemann, H. D. Permeability of wood to air and liquids. So. Lumberman 177: 2223; 68.

Infection by Microorganisms

The occurrence of bacterial infection in the so-called "wetwood" has been reported for 9 genera of tree species and includes several species of Populus.[4] In Lombardy poplar *(Populus nigra italica)* the "wetwood" zone is reported to move outward in the trunk, leaving behind a reddish tissue which later changes to a brown color. That a somewhat similar condition may occur in aspen is indicated by the appearance of many logs (Fig. 4).

In order to ascertain whether bacteria and possibly fungi were present in the material studied, more than 400 cultures were made of sapwood, "wetwood", and heartwood on malt and beef peptone agars. What appeared to be a single bacterium, as yet not identified, was obtained in a high percentage of the cultures from all zones. The general presence of bacteria in sapwood as well as in heartwood and "wetwood" was rather surprising and unexpected. Schmitz and Jackson[7] obtained bacteria occasionally in their isolations, but not in the percentage encountered in this study, about 65 percent of the cultures made.

Wood-rotting fungi were isolated from only two logs, both of which had evident decay in the heartwood caused by *Fomes igniarius*. The general failure to obtain decay fungi in isolations from "wetwood" and discolored heartwood areas indicates that most of the dark-colored wood encountered in aspen heartwood and around knots and other defects is not incipient decay as has been postulated but may be due to bacterial infection or other causes.

The general presence of bacteria in sapwood, "wetwood", and heartwood is suggested as a possible contributing factor to the imperviousness of heartwood "wetwood", and certain areas in the sapwood. That these bacteria may exert a plugging or occluding action similar to that noted in case of certain bacteria causing diseases of plants is certainly within the realm of possibility.

pH of Wood

Pillow[5] found that pH color indicators when applied to the wood showed the high moisture content zone (wetwood) to have a higher pH value than the adjacent sapwood and heartwood, possibly because of the formation of alkaline materials by bacteria present. He suggests that such an indicator might be used to identify wood which is likely to collapse. The authors were unable to obtain consistent results in applying such colorimetric pH indicators, although in many cases a higher pH was indicated for "wetwood". In further study of pH with a Leeds and Northrup pH meter, it was found that the variation of pH within each of the zones exceeded the variation between zones, although the pH of the wetwood generally was higher than that of the sapwood and heartwood.

Strength Tests

Although there is no evidence from the literature that collapse develops in zones or spots in which the wood is weaker, this was considered a possibility in aspen because of the tendency of wood in "wetwood" areas to shrink excessively, check and shake. Also, the roughness of some cuts made with hand and power saws in crosscutting heartwood (Fig. 3) suggested a possible weakness at least of the heartwood.

In order to obtain some data on this point a limited number of strength tests were made. Toughness and compressive strength tests were made on samples cut from the sapwood, "wetwood", and heartwood zones of 16 logs. The number of samples that could be cut from some logs was limited by the fact that very little of the wetwood was wide enough to be sawn into standard sized specimens. Specific gravity determinations were made on specimens from each zone of each log on which strength tests were made. An average of 4 standard toughness and 4 compression test specimens was cut from each zone of each log. The results of these tests are shown in Table 1. Because of the small number of specimens per log, all material from each of the zones was lumped and a single average obtained. All tests were made in the green condition.

Because of the large strength differences obtained between samples cut from the three zones of this group of logs, another set of eight logs was tested. Tests on intermediate zone wood were not included in this test because enough standard sized specimens could

[7] Schmitz, H. and Jackson, L. W. R. Heartrot of aspen. Tech. Bul. 50, Univ. Minn. Agr. Exp. Sta. 1927.

TABLE 1.—RESULTS OF TOUGHNESS AND COMPRESSION TESTS ON WOOD FROM EIGHT ASPEN LOGS

Zone of Wood	Average specific gravity	Number specimens tested	Average toughness value	Average compressive strength parallel to grain
			in.-lbs.	psi
Sapwood	0.381	33	136.8	2511
Intermediate	.375	24	93.8	1884
Heartwood	.343	30	49.5	1852

not be cut from this zone in this particular set of logs to give a good average value. Also, only toughness tests were run because values for this test were so strikingly different from the first group of logs. An average of 12 toughness specimens was cut from each zone of each of these 8 logs. The results on this second group of toughness tests made on green specimens from 8 logs are given in Table 2.

TABLE 2.—RESULTS OF TOUGHNESS TESTS OF SAPWOOD AND HEARTWOOD ON A SECOND SET OF EIGHT ASPEN LOGS

Zone of wood	Average specific gravity of 8 logs	Number specimens tested	Average toughness value
			in.-lbs.
Sapwood	0.391	98	124.2
Heartwood	.350	103	47.7

The surprising similarity between the results obtained on the first and second groups of logs obtained from entirely different locations and picked at random from large stacks of 8-foot bolts certainly indicates that aspen heartwood and possibly the "wetwood" of these logs were considerably weaker than sapwood in the strength tests made. The difference was sufficiently great so that one might expect the presence of decay organisms in the heartwood and possibly in the "wetwood". However, isolations from all of the material tested failed to reveal a single instance of decay in the zones from which test specimens were cut.

The fact that the average specific gravity of heartwood in these logs was approximately 10 percent lower than that of the sapwood suggests further that the heartwood may have been affected in some manner. Although a much larger number of tests on aspen samples from a greater number of locations must be made before conclusions can be drawn on a point as important as this, the data do suggest that aspen heartwood and "wetwood" are considerably weaker in toughness and compressive strength than sapwood. It is suggested that if this difference in strength between sapwood and the wetwood and heartwood of aspen is found to be consistent in further trials that it may be the result of weakening by the bacteria which are so abundantly found in all aspen wood and may be particularly active in the "wetwood" and heartwood. If this is found to be the case it would be the first recorded instance of bacteria affecting wood sufficiently to result in measurable specific gravity and striking strength losses. Added work is planned on this during the coming year.

Although it cannot be definitely stated that lower strength of "wetwood" and heartwood contribute to the formation of collapse, this possibility is certainly not excluded on the basis of the strength values found for the different zones of wood.

Detection and Prevention

Most producers of kiln-dried aspen lumber are well acquainted with the defect caused by collapse and a few of them have adopted measures effective in reducing losses.

The fact that "wetwood", in which most of the collapse occurs, can be detected and identified with some accuracy by the appearance of the ends of logs (Figs. 3 and 4) suggested the possibility of separating the logs containing "wetwood" and sawing and drying the lumber from them separately by air seasoning or under mild kiln schedules. However, it was found that under the operating conditions at most mills this was not practical.

The procedure adopted by one plant making core stock was to kiln-dry from the green condition only clear sapwood boards and such added boards as were definitely free from "wetwood". The remaining material, which included largely heartwood and boards with streaks of "wetwood", were routed to the air-seasoning yard and air-dried prior to kiln-drying. The fact that collapse does not develop

to a serious extent during air-seasoning even in material with considerable "wetwood" makes it possible to dry this material to a point where it can be kiln-dried to the desired moisture content without danger of further losses from collapse.

The use of mild kiln schedules and steaming at the end of the kiln run are other methods of reducing collapse losses. However, the use of mild schedules and the type of steaming needed to restore collapsed areas in aspen boards is expensive and is not considered economical under most Minnesota mill conditions.

At present at least, the procedure for reducing collapse losses adopted by the core stock mill mentioned above is considered the most practical for mills equipped with kilns and drying aspen from the green condition. Separation and air seasoning of boards containing "wetwood" and low-quality heartwood prior to kiln-drying almost eliminates serious collapse in this material and it permits the sapwood to be dried under more rapid kiln schedules with little danger of loss from collapse. Small-mill aspen lumber is normally air-seasoned and losses from collapse in this material should be relatively minor as compared to losses from poor manufacture.

Summary

Collapse was found to be a rather common and serious defect of kiln-dried aspen lumber, particularly for lumber dried under rather drastic conditions or with rapid kiln schedules.

The majority of the collapse was found to develop in boards cut from or including the "wetwood" zone of aspen logs. "Wetwood", either in logs or in green lumber, was found to be readily identifiable by its darker color and wet appearance. "Wetwood" normally occurs as a zone between heartwood and sapwood and appears to be present in only a small percentage of aspen logs.

The wood of the "wetwood" zones was found to be characterized by high moisture content, extreme imperviousness to the passage of air and liquids, uniformity of infection with what appeared to be a single species of bacterium, and weakness in compression and toughness as compared to sapwood.

Separation of boards containing "wetwood" from sapwood boards and air-seasoning this material prior to kiln-drying is an effective method of reducing collapse losses at mills equipped with kilns to dry lumber from the green condition. Small mills commonly air seasoning their product normally have little trouble with collapse.

Additional work on the nature and prevention of collapse in aspen and on the strength of aspen heartwood and "wetwood" as compared to sapwood is planned.

Discussion

Raymond C. Rietz (Forest Products Laboratory): The information given in this paper on the causes of and the remedies for the development of collapse in aspen are significant contributions to our knowledge of the seasoning characteristic of this particular species of wood. I am pleased that the work is to continue, as a better theory than the classical one we now have on collapse may be developed. The authors indicate that the "wetwood" of aspen is heat sensitive, therefore, recommend that control must be gained by air drying lumber containing this high moisture content material. Research sponsored by the Redwood Association has arrived at the same conclusion; namely, that if sinker stock is to be dried without serious losses due to collapse it must first be air dried. A number of other species have this same seasoning problem.

The authors associate collapse in aspen with high moisture content impervious to air and liquids and infection with bacteria. As previously supposed, decay organisms are not always present. Strength tests indicate the likelihood of reduced strength due to unknown causes. The tests made were compression parallel to grain and toughness. I would like to suggest that in their future studies that the strength in tension perpendicular to the grain be studied as a function of moisture content and temperature, as it is the weakness in this direction which results in the defects observed.

Dr. Kaufert: Some studies have been conducted on the impregnation of wood which tends to collapse with gas forming chemicals so that the terrific stresses placed on the cell walls by the reduction in water content of the

cell cavity will be avoided by the introduction of a gas into the cell cavity in spite of the imperviousness of the cell wall. The studies were not too successful but offer a possible remedy where segregation and air drying isn't considered economic.

R. D. Carpenter (U. S. Forest Service): Can collapse tendencies be detected in logs that have been cut for some time and the ends thus somewhat affected by weathering, or must examination for such tendencies be applied to freshly-cut logs?

Dr. Kaufert: During the winter months when logs are frozen it is possible to detect readily logs containing "wetwood", even after several months. In the summer, however, it is difficult to identify such material for more than a few weeks after cutting.

Arlie W. Toole (Michigan College of Mining and Technology): Dr. Kaufert's paper presents some very interesting results both from the standpoint of extending our basic knowledge of a particular wood species and its possible application to improvement of operating practices.

The rapid decline in toughness with reduction in specific gravity observed between sapwood and heartwood may well be of considerable practical signficance. Whereas the reduction in specific gravity is of the order of ten percent, the corresponding reduction in toughness is of the order of sixty percent. For some uses of aspen this might be a factor in its utilization.

I have two questions I would like to ask Dr. Kaufert.

1. Does heartwood in mature aspen commonly comprise a high percentage of the cross-sectional area of the tree or bolt?
2. Is the lower specific gravity of heartwood as compared to sapwood always or generally associated with the presence of "wetwood"?

Dr. Kaufert: Observations by the writers indicate that the extent to which heartwood occupies the cross-sectional area of mature aspen varies greatly. Logs as large as 30 inches in diameter with little apparent heartwood have been observed. Observations on hundreds of aspen veneer bolts indicated that some had heartwood almost completely covering the cross-sections, whereas in others heartwood appeared to be entirely lacking. All degrees of variation between these extremes were observed. Sufficient data are not available at this time to make any generalization regarding the frequency as related to percentage of cross-sectional area occupied by heartwood.

In answer to Mr. Toole's second question it may be said that, with one exception, specific gravity of heartwood was less than that of the sapwood in every log studied, regardless of whether wetwood was evident.

FOREST PRODUCTS RESEARCH SOCIETY

Control of Wood-Boring Insects in Green Logs and Lumber

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Damage by wood-boring insects presents an increasingly difficult problem to timber operators. Changes in operational requirements during recent years have made impractical the handling methods previously employed in protecting timber from attack by wood-boring insects. This paper presents the results of tests conducted for the control of such insects, particularly ambrosia beetles, by the application of insecticides. Benzene hexachloride has performed very effectively in the protection of both logs and lumber.

Introduction

THE protection of green timber from insect attack has always been considered a problem to be solved by proper handling methods. The rapid movement of logs from the woods to the mill and their immediate conversion into lumber has been considered a necessity. The floating of logs in fresh water, even the actual sinking of some species, is also practiced in the effort to prevent attack by sawyers, ambrosia beetles, and other wood-boring insects. Storage of logs in open fields is another method, though of questionable value, utilized particularly for the control of ambrosia beetles. All these methods have merits under certain conditions, but each has definite limitations. Prompt handling of logs and conversion into lumber is certainly the most effective method of preventing insect attack and general deterioration of the timber. It is frequently impracticable and expensive, however, particularly when timber operators, especially those in the South, must reach into woodlands far from the mills and into areas accessible only during the few dry months of the year. Timber must be logged, trucked, and stored in quantities sufficient to maintain continuous operation of the mill during the fall and winter months. This is true for the most part of the hardwoods, but it also applies to the softwoods.

In recent years the problem of insect control has become an important consideration with respect to importation of tropical timbers. Many reports have been received that damage to valuable logs by insects, particularly by ambrosia beetles, has been very severe. While precautions have been taken to prevent attack by floating the logs and moving them rapidly to the mill, beetle populations in the Tropics are so great and active that protection of the timber is difficult. Requests for information on insecticidal control methods have been numerous.

The problem of preventing insect attack of green timber through the use of insecticides has always been a difficult one. In 1922 Craighead[1] presented the difficulties and reported results of tests with numerous insecticidal formulations. Treatments did not offer protection over the desired period of time or they were impractical for other reasons. Ambrosia beetles were particularly difficult to control. Perhaps the most extensive investigations were those of Christian[2] on the control of ambrosia beetles. Christian investigated the value of treating hardwood lumber by dipping and spraying methods, giving particular attention to the latter. He tested more than 100 formulations. Four were found to be effective and one offered some promise of being used on a practical scale. Dichlorodiphenyl oxide in kerosene 1:3 became widely used for preventing damage to green logs and lumber by ambrosia beetles. However, this formulation left much to be desired. Under severe exposure one spray application protected logs for only 1 to 2 months, the chemical could not be readily adapted to lumber treatment, and the cost of protection was too high.

In 1944 and 1945 small-scale exploratory tests were conducted by the Bureau of Ento-

[1] Craighead, F. C. Experiments with spray solutions for preventing insect injury to green logs. U. S. Dept. Agr., Prof. Paper Bul. 1079, 11 pp. 1922.

[2] Christian, M. B. Experiments on the prevention of ambrosia beetle damage in hardwoods. South. Lumberman 159:110–112. 1939.

mology and Plant Quarantine at Gulfport, Miss., to determine the value of DDT in controlling ambrosia beetles. Results were so promising that tests were expanded in 1946 to include various formulations of DDT. Benzene hexachloride and chlordane were also given preliminary tests. Benzene hexachloride offered protection superior to any material previously tested. In 1947 and 1948 numerous formulations of this chemical and other recently developed synthetic organic insecticides were intensively tested at cutting sites and lumber mills at six different locations in Alabama, Louisiana, and Mississippi. Studies included different formulations of various chemicals and different methods of application directed toward their practical use by timber operators in protection of logs and lumber.

Since 1947 an effective oil formulation of benzene hexachloride has been recommended to timber operators urgently in need of measures for protecting green logs from insect attack. Operators in this country and Central America have reported very favorable results. One large operator reported highly successful results with this treatment when it was adopted following repeated failures with oil solutions of DDT. British workers have recently reported benzene hexachloride to be effective in preventing attack of logs by ambrosia beetles and have pointed out its superiority over DDT in offering greater protection over a longer period.[3]

Results of tests conducted during 1946, 1947, and 1948 are presented in this paper. Emphasis is placed on the control of ambrosia beetles, in view of the importance of the problem and intensive studies conducted in relation to it. Some attention is devoted to the protection of pine timber from attack by bark beetles and borers.

Protection of Green Hardwood Logs

Description of Insects and Damage

There are several species of ambrosia beetles. *Xyleborus affinis* Eich. (family Scolytidae) and *Platypus compositus* Say (Platypodidae) cause the greatest damage to southern hardwood timber.[4] The adults are tiny, elongate beetles, 2.5 to 4.5 mm. long, cylindrical and short-legged, with dull brown to black coloration. They attack dying trees and green logs and lumber. The adult beetles damage timber by tunneling throughout the wood. In this tunneling they introduce and propagate ambrosia fungi, upon which adult beetles and their progeny feed. The particular fungi associated with some species of ambrosia beetles cause a dark staining of the wood surrounding the gallery. Hubbard[5] gives a detailed account of the feeding habits and life history of ambrosia beetles with respect to the fungi they introduce.

Another insect causing considerable damage to green hardwoods is the red-shouldered beetle, *Xylobiops basilaris* Say (family Bostrichidae). It attacks trees of low vigor, including dying trees, and freshly cut and partially seasoned logs, particularly those of hickory, pecan, and persimmon. Adults and larvae excavate numerous tunnels, up to 5 mm. in diameter, throughout the wood.

Less common are long-horned borers (Cerambycidae) and flatheads (Buprestidae) which may severely damage green timber by cutting large galleries throughout the wood.

Screening Tests With Red Gum Bolts

A large number of screening tests were conducted in order to eliminate chemicals and formulations lacking promise for preventing beetle attack. Forty formulations were tested during the three summer seasons. Two-foot sections of small red gum trees (5 inches d.b.h.) were placed in groups of 10, 12, or 14 samples, each group containing sections from different trees and from consecutive positions within the trees. All bolts within a group were then treated with the same formulation. To eliminate any variation in chemical application, all bolts were given an instant dip in the chemical, with the exception of treatments with concentrated materials which were applied with a fog sprayer. After being treated each group was piled in a location favorable for beetle attack. Three to four months later all bolts were peeled and counts were made of beetle penetration into the wood. The relative effec-

[3] Fisher, R. C. DDT and control of Lyctus powder-post beetles. Empire Forestry Rev. 27:303–305. 1948.

[4] Blackman, M. W. Mississippi bark beetles. Miss. Agr. Exp. Sta., Tech. Bul. 11, 130 pp. 1922.

[5] Hubbard, H. G. The ambrosia beetles of the United States in: Some miscellaneous results of the work of the Division of Entomology. U. S. Dept. Agr., Div. Ent., Bul. 7, pp. 9–30. 1897.

tiveness of the different treatments is indicated in Table 1.

All factors considered, the most satisfactory treatments were those in which technical benzene hexachloride was used at the rates of 14 pounds (12 percent gamma) and 4.66 pounds (36 percent gamma) per 50 gallons of No. 2 fuel oil. In 12 tests of these formulations there was an average of three beetle holes per square foot of surface area as compared with 23 per square foot in untreated bolts. Increasing the amount of benzene hexachloride from 14 pounds to 28 pounds improved the effectiveness very slightly. There is considerable indication that benzene hexachloride is more effective in No. 2 fuel oil than in light oils such as kerosene.

Two percent of pentachlorophenol was included in some of the oil formulations of benzene hexachloride and DDT in order to test the effectiveness of such solutions in preventing infection by decay and staining fungi. The tests showed positively that these organisms were controlled and that pentachlorophenol had no adverse influence on the insecticidal effectivness of benzene hexachloride and DDT.

Fog sprays showed considerable promise in these tests. As will be noted later, application of concentrated insecticides in this manner is often a very practical method. Tests this season were the first conducted and were largely exploratory. All applications were made with a Banta–Driscoll fog sprayer—a light, backpacked, precision-tooled instrument provided through the courtesy of the Banta–Driscoll Corporation. The success of this method calls for future testing of the fog machine as well as larger types of mist blowers now in production.

Emulsions, while not so effective as oil solutions, show some promise and deserve further study, particularly in view of their low cost.

TABLE 1.—EFFECTIVENESS OF VARIOUS DIP AND SPRAY TREATMENTS IN PREVENTING AMBROSIA BEETLE ATTACK ON RED GUM BOLTS

Treatment	Lb. (or gal.) of insecticide per 50 gal. of carrier	Percent control
Oil solutions—dips		
Benzene hexachloride (12 percent gamma):		
In No. 2 fuel oil	14, 28	80–100
In kerosene	14, 28	60– 80
Benzene hexachloride (36 percent gamma) in No. 2 fuel oil	4.66	80–100
Benzene hexachloride (proprietary):		
Penco E–11 in No. 2 fuel oil[1]	1.75 gal.	60– 80
Ambrocide (ready-to-use)[2]	Undiluted	60– 80
Ambrocide (1:19) in No. 2 fuel oil[2]	2.63 gal.	60– 80
Benzene hexachloride (12 percent gamma)+DDT in No. 2 fuel oil	7.0+8.4	40– 60
DDT in No. 2 fuel oil	16.7, 33.4	40– 80
DDT in kerosene	16.7, 33.4	0– 20
DDT in benzene	33.4	0– 20
Chlordane (20 percent) in No. 2 fuel oil	1.25, 2.5, 5 gal.	0– 20
Methoxychlor in No. 2 fuel oil	33.4	0– 20
Toxaphene in No. 2 fuel oil	33.4	0– 20
Monochloronaphthalene in kerosene	5.5 gal.	0– 20
Dichlorodiphenyl oxide in kerosene	16.7 gal.	0– 20
Piperonyl butoxide in No. 2 fuel oil[3]	5.5 gal.	0– 20
Piperonyl cyclonene in No. 2 fuel oil[3]	5.5 gal.	0– 20
Emulsions—dips		
Benzene hexachloride (36 percent gamma) in benzene+Triton X–100	4.66	60– 80
Benzene hexachloride (proprietary):		
Penco E–11	1.75 gal.	60– 80
Ambrocide (1:19)	2.63 gal.	80–100
DDT in benzene+Triton X–100	33.4	40– 60
DDT in benzene+glyceryl oleate	33.4	40– 60
Piperonyl butoxide[4]	5.5 gal.	0– 20
Piperonyl cyclonene[4]	5.5 gal.	0– 20
Suspensions—dips		
Benzene hexachloride (6 percent gamma) (50 percent wettable)	28.0	40– 60
Fog applications		
Benzene hexachloride (36 percent gamma):		
In benzene	186.5	60– 80
In benzene+fuel oil (1:1)	93.2	80–100
In cyclohexanone	280.0	80–100
In cyclohexanone+fuel oil (1:1)	140.0	80–100
Controls—dips		
No. 2 fuel oil, kerosene, benzene+Triton X–100, untreated	----------	0– 20

[1]Emulsifiable solution containing 11 percent of gamma isomer. Provided by the Pennsylvania Salt Manufacturing Company
[2]Ambrocide (ready-to-use) contains 0.485 percent of gamma isomer; Ambrocide (1:19) contains 8.28 percent of gamma isomer
[3]Oil concentrates containing in addition a quantity of rotenone. Provided by Industrial Chemicals Corporation.
[4]Emulsion concentrates (as in 3).

All formulations of benzene hexachloride that gave considerable protection from ambrosia beetle attack were completely effective against other wood-boring insects.

Tests With Sawlogs

In view of the promising results obtained with benzene hexachloride in screening studies, tests were begun in 1947 to evaluate its performance when applied by conventional spraying methods under conditions encountered at mill banking yards. In early tests benzene hexachloride (12 percent gamma) was applied with a common hydraulic power sprayer operating at about 400 pounds' pressure and a delivery rate of 4 gallons per minute. The sprayer was equipped with a non-adjustable gun which delivered a coarse spray. In one series of tests 15 to 20 red gum logs were sprayed individually at the rate of 1 gallon of solution per 100 square feet of bark area, and then decked. In another series entire decks were sprayed as the logs were dropped from trucks. After 3 to 4 months' exposure ambrosia beetle entrance holes were counted. One-third of the logs were sampled, the counts being obtained from one-foot sections taken at three points in each log. Data showed that good protection of logs was possible only when each log was sprayed individually.

In 1948 efforts were made to improve methods of application in order that effective protection might be attained when entire log decks were sprayed. A small hydraulic sprayer was used which operated at about 200 pounds' pressure and a delivery rate of 2 gallons per minute. Two types of nozzle apparatus were employed: (1) A spray gun which allowed adjustment of the spray from a wide cone-shape pattern, used in treating easily accessible areas of the decks, to a long, narrow cone pattern, used in reaching less accessible areas; (2) a spray gun which delivered a fixed, large cone spray pattern, an extension rod being attached to enable the operator to reach areas not easily accessible.

Hydraulic sprayers were employed in spraying individual logs and entire decks by the procedure outlined above at 14 pounds of benzene hexachloride (12 percent gamma) per 50 gallons. In addition a concentrated spray of benzene hexachloride was applied by means of the Banta–Driscoll fog sprayer to entire decks. The concentrate, 186.5 pounds of 36 percent gamma per 50 gallons, was applied at the rate of about 1 quart per 800 square feet of bark area.

When individual logs were sprayed, ambrosia beetle attack was very light. When log decks were sprayed with the hydraulic sprayers it was light to very light, and with the fog sprayer medium to very light. These results indicate that satisfactory protection of logs by spraying entire decks is possible if proper apparatus is employed. The apparatus capable of producing a fine-droplet spray is preferable; otherwise an extension rod must be used to reach poorly accessible areas of the deck. The fog spray was very effective in some tests, less so in others. It appears very promising, but the erratic results obtained demand further investigation.

Other wood-boring insects were almost completely controlled by the sprays tested.

Tests With Felled Trees

Red gum trees of sawlog size were used to determine further the value of protective sprays in preventing ambrosia beetle attack. The tests were more severe than the previous tests in that generally the tree remained susceptible to attack over a longer period of time and usually in situations where beetle populations were heavy. The trees were felled, trimmed, and marked off into 4-foot units separated by one-foot buffer zones. Each chemical formulation was sprayed on a 4-foot unit in different trees and in different positions in the tree. After 3 to 4 months' exposure, beetle-entrance holes were counted in 1-foot sections of each sprayed unit to determine the effect of the insecticide. Twenty-seven trees were used in five series of tests.

Detailed results of the tests are not being presented, since the treatment values are very similar to those obtained in tests already described. The 12-percent-gamma grade of benzene hexachloride was applied with a conventional sprayer at concentrations of 3.5, 7, 14, and 28 pounds per 50 gallons of No. 2 fuel oil. The 36-percent-gamma product was applied similarly at a concentration of 4.66 pounds in oil and in emulsion, and in addition was applied with the fog sprayer at 186.5 pounds

in benzene and 280 pounds in cyclohexanone per 50 gallons of these carriers. DDT was applied in fuel oil at 16.7 and 33.4 pounds per 50 gallons. Dichlorodiphenyl oxide was applied at 16.7 pounds in kerosene. Two percent of pentachlorophenol was added to some of the benzene hexachloride and DDT formulations.

The 14-pound concentration of 12-percent-gamma benzene hexachloride appeared most promising from the standpoint of practical application. DDT and dichlorodiphenyl oxide were completely unsatisfactory.

Protection of Green Lumber

The protection of green lumber against ambrosia beetle attack is not so serious a problem as that of logs. If proper handling methods are utilized and the moisture content of the lumber is reduced below 50 percent, there is no danger of attack. However, during prolonged spells of damp weather the wood dries slowly and remains susceptible to beetle attack.

A number of formulations, particularly of benzene hexachloride and DDT, were effective in protecting lumber for about 3 months whether applied by dipping, a conventional sprayer, or a fog sprayer. Concentrations less than half of those used in log protection were found to be quite adequate. However, the treatment which allows the greatest safety margin and appears to be most practical is a dip or thorough spray application of benzene hexachloride emulsion at a concentration of 2.33 pounds of 36-percent-gamma material in 50 gallons. Under most conditions it is desirable to use a stain preventive with the insecticide. The common stain preventives on the market today were used in combination with emulsions and suspensions of benzene hexachloride and DDT and found entirely compatible with respect to prevention of insect and stain damage; concentrations were those recommended by the manufacturer. The stain preventives tested were Lignasan, Dowicide G, and Permatox 10-S. A small-scale test conducted in cooperation with the Bureau of Plant Industry, Soils, and Agricultural Engineering[6] further substantiated the compatibility of insecticides with these stain preventives.

[6] Verrall, A. F. Unpublished report.

Screening Tests

Screening tests were conducted in which groups of 5 to 10 samples of freshly cut red gum 2 by 4 by 18 inches and 1 by 4 by 18 inches were given an instant dip in different insecticide formulations. Entrance holes were counted in all samples after an exposure of 3 to 4 months. No attempt will be made to present the numerous formulations and detailed data obtained in connection with these studies. Some general observations are given below.

1. Oil solutions of benzene hexachloride (12 percent gamma) in four concentrations ranging from 3.5 to 28 pounds per 50 gallons of No. 2 fuel oil or kerosene were very effective.
2. Emulsions of benzene hexachloride (36 percent gamma) in four concentrations ranging from 0.58 to 2.33 pounds per 50 gallons were effective at the highest concentrations.
3. Proprietary emulsions of benzene hexachloride, Ambrocide (1:19) and Penco E-11, were most satisfactory when used at high concentrations of 2.63 and 1.75 gallons, respectively, per 50 gallons.
4. Suspensions of benzene hexachloride, 50-percent wettable (6 percent gamma), used in five concentrations from 3.5 to 55.8 pounds per 50 gallons of water, were most consistently effective at 28 and 55.8 pounds.
5. Solutions of DDT in No. 2 fuel oil, kerosene, and benzene were very effective when used at concentrations of 16.7 and 33.4 pounds per 50 gallons.
6. Emulsions of DDT in concentrations of 4.2, 8.4, and 33.4 pounds per 50 gallons gave good control only in the highest concentration.
7. Suspensions of DDT (50 percent wettable) in four concentrations from 8.4 to 66.8 pounds per 50 gallons of water were effective at the highest concentration.
8. Dichlorodiphenyl oxide, 25 percent in kerosene, was effective.
9. Piperonyl butoxide and piperonyl cyclonene in emulsion gave fair results.
10. Monochloronaphthalene in kerosene and ammonium fluoborate in water were completely ineffective.

11. A suspension of methoxychlor (50 percent wettable) was ineffective at 66.8 pounds per 50 gallons of water.
12. DDT-colloidal (40 percent) was ineffective at 1.25 gallons per 50 gallons of water.

Large-Scale Tests

Large-scale tests were undertaken in 1948 to determine the value of treatments in preventing ambrosia beetle attack on full-dimension lumber under conditions of severe exposure. In one test 16-foot boards were sprayed individually (simulating dip treatment as closely as possible) with emulsio ns of 1.16 and 2.33 pounds of benzene hexachloride (36 percent gamma) per 50 gallons. Boards were then stacked in piles 3 by 6 by 16 feet in heavy shade where beetle activity would be great. These emulsions were also sprayed on similar stacks already erected, with a power sprayer and spray gun capable of producing variable spray patterns. The rate of application was about 18 gallons per M board feet. To another stack a concentrate containing 186.5 pounds of benzene hexachloride (36 percent gamma) per 50 gallons of benzene was applied as a fog spray at the rate of 3 pints per M board feet. A stack of unsprayed lumber served as a control. After 3 months' exposure beetle holes were counted in two 1-foot strips across each layer of lumber.

Almost complete control of ambrosia beetles was obtained from all treatments. The results indicate that effective protection is possible with emulsions applied either by dipping lumber in vats as it comes off the saw or by spraying entire stacks. Spraying has a particular advantage in that treatment may be applied at first evidence of beetle activity and the expense of treating all lumber regardless of the presence of beetle populations thus eliminated. However, the method does require checking of lumber stacks and spray application must be made carefully and thoroughly. Fogs or mists of insecticide concentrates offer an especially promising method of control. The cost of the chemical per M board feet does not exceed that of emulsions, and labor costs are reduced considerably owing to the speed of application. However, the method has not yet received the intensive testing given emulsion treatments.

Recommendations for Preventing Insect Damage to Hardwood Logs and Lumber

Treatment of Logs

Best results in treating hardwood logs can be obtained with an oil solution of benzene hexachloride, which costs approximately 23 cents per gallon. The solution is prepared simply by dissolving the required amount of the chemical in No. 2 fuel oil. Since manufacturers produce technical benzene hexachloride containing different percentages of the toxic gamma isomer, the quantity of chemical necessary to prepare an effective concentration varies. The following information will be useful in prepartion of the insecticide:

Percent of gamma isomer	Pounds of chemical per 50 gallons of oil
10	17
12	14
36	4.66

The solution should be agitated thoroughly. The action may be speeded up by allowing the heat of the sun to raise the temperature of the oil. A small amount of residue, consisting of impurities, will settle out in the mixing container.

Pentachlorophenol should be added to the solution if sap stain is to be prevented. A two percent concentration has been found effective for this purpose. Prepared concentrates are more easily handled than the crystalline form of pentachlorophenol.

Emulsions, though somewhat less effective than oil solutions, may be used to advantage in certain situations, particularly when beetle attack is not unusually severe or protection for less than 2 months is necessary. Home-made emulsions of the required concentration cost about 14 cents per gallon. Such an emulsion may be prepared by completely dissolving 7.5 pounds of benzene hexachloride (36 percent gamma) in 2 gallons of benzene. Add 1.5 gallon of this stock solution to 45 gallons of water, follow with 1 pint of Triton X-100 or other suitable emulsifier, and agitate. There are a number of emulsion concentrates on the market which in certain situations may be more desirable, but they are more expensive. A water-soluble stain preventive should be added to the treating solution. Any of the common mate-

rials, such as Santobrite, Dowicide G, Permatox 10-S, or Lignasan, may be used. The manufacturers' suggested concentrations for lumber treatment should be tripled.[7]

Logs should be sprayed as soon as possible after being bucked, preferably within 48 hours. Sap-stain fungi become established and develop rapidly, although insect attack may not begin before 7 to 10 days. Sprays must be applied carefully and thoroughly, if the treatment is to be effective. A 12-inch log 16 feet long requires about ½ gallon of insecticide, a 24-inch log of the same length about 1 gallon, and a 48-inch log about 2 gallons.

The cost of the treatment varies with the diameter of the logs. For oil solutions the cost per M board feet by the International Log Scale ranges from 45 cents for logs 2.5 feet in diameter to $1.30 for logs one foot in diameter. Treatments with emulsions cost 25 cents and 75 cents per M board feet, respectively. The cost of stain preventives has not been included in these figures.

Direct sunlight breaks down benzene hexachloride. Generally ambrosia beetles will not attack logs exposed to direct sunlight. However, it is suggested that, once sprayed, logs should not be turned or moved to positions enabling beetles to attack where the insecticide has been dissipated. In the Tropics, where excessive rainfall, sunlight, and high temperatures probably have adverse effects on the insecticide, spraying every 2 months may be desirable.

Treatment of Lumber

Application of benzene hexachloride emulsions to lumber by dipping or spraying is considered very effective and economical. Application of concentrated solutions in fog or mist form offers distinct possibilities if proper equipment is used.

The emulsion may be prepared exactly as outlined for treatment of logs except that half the amount of stock solution should be added to 45 gallons of water. If the material is to be applied as a spray, a sap-stain preventive should be added in the concentration recommended by the manufacturer. If a dip treatment is employed, the insecticide may be applied in the dipping vat along with stain preventives in use. Sprays must be applied very thoroughly in order to contact all wood surfaces within lumber stacks.

Spraying or dipping requires about 20 gallons of emulsion per M board feet of 1-inch lumber. The cost of such a treatment is about $1.50 per M board feet.

A fog or mist application is recommended with some hesitation. While results of tests were very satisfactory, they are based on the study of one piece of equipment. It is conceivable that some types of apparatus, such as those depending on air blast for mist formation, might not be effective. It is reasonable to expect, however, that any equipment having a delivery rate of about 6 ounces per minute and producing a slow-moving fog will give satisfactory results. If fog applicators are employed, the stock solution of benzene hexachloride (36 percent gamma) in benzene, mentioned for log treatment, should be used without dilution. It should be applied at the rate of about 3 pints per M board feet of 1-inch lumber. The cost of this treatment is about $1.50 per M.

Prevention of Lyctus Attack

Lumber in storage frequently becomes infested with Lyctus powder-post beetles, which will attack before the wood is thoroughly seasoned and continue to reinfest it as long as conditions are favorable. This is true particularly of ring-porous woods, such as hickory, pecan, ash, oak, and a few of the semi-ring-porous species. One of the measures commonly recommended for preventing attack is a dip treatment in a water suspension containing 1 percent of wettable microfine sulfur. In studies on lumber treatment it was found that sulfur is compatible with combinations of benzene hexachloride or DDT with sodium pentachlorophenate. Thus it is possible in one operation to apply treatments for the control of ambrosia beetles and Lyctus powder-post beetles and sap stain.

Control of Bark Beetles and Borers Attacking Pine

Losses of considerable magnitude are caused by damage to pine logs and pulpwood as a

[7] Triple concentrations are generally effective in preventing fungus attack to hardwood logs when insect attack is negligible. Stain preventives can be used alone for preventing fungus attack during seasons when insect attack is not prevalent.

result of attacks by bark beetles, sawyers, and other wood-boring insects. Greatest damage is caused by the sawyers or long-horned borers (*Monochamus* spp.), which excavate large galleries throughout the wood, often destroying sawlogs and seriously reducing the quality of pulpwood used in manufacture of paper, wallboard, and other cellulose products. Bark beetles, particularly *Ips* spp., are injurious mainly from the standpoint of the sap stains they introduce.

In 1944 and 1945 preliminary studies were conducted to determine the value of DDT for the prevention of bark beetle and borer attack. Erratic results were obtained. In 1944 some control was obtained with concentrations of 0.5, 1, and 2 percent of DDT in kerosene; in 1945 concentrations of 4 and 8 percent in diesel oil, kerosene, emulsions, and suspensions, and 10 and 50 percent dusts all gave unsatisfactory results. These inconsistencies were never completely explained.

In 1947 a small-scale test with DDT and benzene hexachloride revealed that, while DDT performed well at concentrations of 4 and 8 percent in No. 2 fuel oil, benzene hexachloride (10 percent gamma) was considerably more effective at a concentration of 0.8 percent gamma in No. 2 fuel oil (34 pounds per 50 gallons).

In the summer and fall of 1948 a series of tests was begun to evaluate the effectiveness of benzene hexachloride in comparison with DDT, chlordane, and toxaphene.

Screening Tests With 2-Foot Bolts

Studies were conducted in the manner described under screening tests with red gum bolts. In one series of tests groups of bolts were treated with different formulations immediately after cutting as a preventive treatment. In another series bolts were exposed to insect attack for 2 weeks and then treated as in the first series as a remedial measure. All bolts were given instantaneous dips except those to which fog applications were made. After about 3 months' exposure the bolts were peeled and counts made.

Results of these tests are shown in Table 2. All preventive treatments were largely effective in preventing sawyer attack and in keeping bark beetle attack and development to a minimum. However, chlordane allowed considerable stain introduction by the bark beetles. Among the remedial measures, all treatments except fog applications arrested bark beetle activity and gave fair to very good control of borers. DDT, though applied in high concentrations, continued the inconsistent behavior observed in previous tests. Benzene hexachloride in oil appears to be the most practical treatment when both effectiveness and cost are considered.

Spray Treatment of Pulpwood

Tests were conducted to determine the effectiveness of insecticides when applied to piles of pine pulpwood with a garden-type sprayer, (1) at the time of cutting and (2) 1, 2, and

TABLE 2.—EFFECT OF PREVENTIVE AND REMEDIAL TREATMENTS IN CONTROLLING SAWYER AND BARK BEETLE DAMAGE

Treatment	Insecticide per 50 gal. of carrier	Preventive		Remedial	
		Ips galleries	Sawyer tunnels	Ips exit holes	Sawyer tunnels
	Pounds	Number per square foot			
Dips—oil solutions in No. 2 fuel oil					
Benzene hexachloride (12 percent gamma)	7	0.04	0.00	0.00	.43
	14	.04	.00	.00	.17
Chlordane (20 percent)	1.25 gal.	.59	.00	.33	.54
Toxaphene	33.4	.14	.00	.00	.54
DDT	21	.00	.00	.00	1.15
	42	.14	.00	.00	2.20
Dips—water emulsions					
Benzene hexachloride (36 percent gamma) in benzene+Triton X-100	4.66	.28	.00	1.05	.67
Fog applications					
Benzene hexachloride (36 percent gamma) in benzene	186.5	.14	.00	2.17	3.00
Controls					
Untreated	------	5.23	4.41	17.0	3.80
No. 2 fuel oil	------	.95	1.00	3.50	4.29
2 percent pentachlorophenol	------	.86	.00	11.21	2.96

3 weeks after cutting. The latter treatment was included in view of the need for effective methods of controlling severe infestations when it is impossible to apply preventive sprays.

In testing preventive sprays entire piles of pulpwood approximately one-eighth of a cord in volume were thoroughly sprayed within a few hours after trees had been felled and bucked. After about 3 months' exposure one-third of the sticks were peeled and counts made. Results are presented in Table 3.

Pentachlorophenol was added to all DDT and benzene hexachloride oil formulations in all tests with pine insects. The addition of a two-percent concentration of pentachlorophenol appeared to reduce the attack by stain and decay organisms. However, much more work is needed before a definite recommendation can be made for adding a fungicide to the insecticidal solution for the treatment of pine logs and pulpwood. It appears that the amount of staining varies directly with the severity of bark beetle and borer attack.

TABLE 3.—RESULTS OF SPRAYING PINE PULPWOOD TO PREVENT ATTACK BY BARK BEETLES AND BORERS

Treatment[1]	Pounds of insecticide per 50 gal. of fuel oil	Ips		Sawyer tunnels	Stain
		Galleries	Exit holes		
		Number per square foot			
Benzene hexachloride (12 percent gamma)	7	0.00	0.00	0.00	Very light
	14	.42	.18	.06	Light
DDT	21	2.32	7.61	1.68	Heavy
	42	.55	2.90	.18	Light
Untreated	--	4.32	24.54	5.00	Heavy

[1] 1 percent of pentachlorophenol added in first treatment; 2 percent in all others.

The information in the table is rather clear cut except for the unusual difference in the benzene hexachloride treatments, which may be attributed to the expected lack of uniformity of distribution when a garden sprayer is used for spraying an irregular unit such as a pulpwood pile.

The test of remedial measures, which included treatments listed in Table 3 and also orthodichlorobenzene in No. 2 fuel oil (1:4), was considered unsatisfactory. Generally the benzene hexachloride and DDT treatments were effective and compared favorably with orthodichlorobenzene, which has for some time been a standard control measure. However, a great deal of variation prevailed within treatments and little difference between treatments. It is believed that considerable study must be given to spray apparatus for controlling existing infestations in pulpwood piles.

These studies point out rather clearly the value of benzene hexachloride in preventing infestation of pine by bark beetles and wood borers. The preferred treatment appears to be 14 pounds of benzene hexachloride (12 percent gamma) in 50 gallons of No. 2 fuel oil. A cord of pulpwood may be sprayed with this solution at a cost of about 85 cents. About 2.5 gallons of solution are required per cord.

Precautions for Handling Chemicals

Most insecticides are potentially toxic to man and animals and should therefore be handled with care. Benzene hexachloride is absorbed through the skin when it is contained in oil or other solvents. Pentachlorophenol solutions are irritating to the skin. Therefore, efforts should be made to avoid excessive bodily contact with these materials by wearing adequate clothing. When contact is unavoidable, adverse effects may be prevented by thorough washing with soap and water. Benzene is very inflammable, as well as highly irritating, and should therefore be used with great care.

Sources of Supply

The following companies manufacture or distribute benzene hexachloride:

South Atlantic Chemical Co., Charleston, S. C.

Thompson–Hayward Chemical Co., 3111 Lowerline St., New Orleans, La.

A. D. Chapman Chemical Co., 707 Dermon Building, Memphis 3, Tenn.

Westvaco Chlorine Products Corp., 405 Lexington Ave., New York 17, N. Y.

California Spray-Chemical Corp., Richmond, Calif.

Dow Chemical Co., Midland, Mich.

Pennsylvania Salt Mfg. Co., 1000 Widener Building, Philadelphia, Pa.

E. I. duPont de Nemours and Co., Wilmington 98, Del.

Commercial Solvents Corp., 17 E. 42nd St., New York 17, N. Y.

Niagara Sprayer and Chemical Division, Food Machinery Corp., Middleport, N. Y.

The following companies handle pentachlorophenol:

Dow Chemical Co., Midland, Mich.

A. D. Chapman Chemical Co., 707 Dermon Building, Memphis 3, Tenn.

Monsanto Chemical Co., 1700 S. Second St., St. Louis, Mo.

No attempt has been made to make the list complete. No discrimination is intended or implied against firms whose products have not been mentioned; nor is the list an endorsement of quality or price.

Discussion

Robert L. Krause (E. I. DuPont de Nemours and Co.): Dr. Kowal and his coworkers are to be complimented on their discovery of a chemical treatment which will effectively control wood boring insects which cause serious degrade on both logs and lumber. The treatment is not only effective, but Kowal's work shows that the treatment can be applied simply and that it should provide important savings. Reduction in losses due to degrade from beetle attack will help conserve our timber supply because it will permit the lumberman to produce a greater amount of high grade lumber from a smaller cut. This will also result in direct savings in operational costs.

Successful control of beetles on stored logs should also permit the operator to start banking logs earlier. This is important in many areas where a log supply must be built up to carry over the winter season. Very often the operator delays his banking in order to avoid severe losses from beetle attack and he may have to continue his logging operations under adverse weather conditions which result in excessive damage to his roads and equipment.

I would like to ask a few questions regarding the effectiveness of benzene hexachloride:

(1) Have you been able to determine how long a single spray application on logs will remain effective?

(2) Is there evidence that benzene hexachloride may not be effective against some of the more important wood boring insects?

(3) Has anyone determined whether benzene hexachloride is effective against *Lyctus* beetles?

Dr. Kowal: Our tests show definitely that one application of benzene hexachloride in concentration of 0.5 percent gamma in fuel oil No. 2 will protect logs for a period of three to four months. I would like to emphasize the fact that all of our tests were conducted under particularly severe exposures. Therefore, if logs are stored during periods when or in areas where beetle populations are low, the period of protection will probably extend well beyond four months.

Our tests indicate that the formulation just mentioned is effective against all of the important wood boring insects which attack green logs and lumber. While our studies with hardwoods were concerned largely with ambrosia beetles in gum, it was observed that logs of pecan, ash, hackberry, oak and other species within our tests as well as those sprayed by timber operators were free of attack by the numerous cerambycid and buprestid borers (round-headed and flat-headed borers) found in untreated logs.

Preliminary results indicate that benzene hexachloride has some value in controlling *Lyctus*. It is much too early to make any conclusions in this regard or to make any comparisons with other new insecticides being tested or with chemicals now being used commercially. My own opinion is that benzene hexachloride, used alone, will not exhibit any outstanding qualities. Its greatest value will probably be in the protection of green lumber from *Lyctus* attack.

I cannot over-emphasize the importance of thorough spraying of logs and lumber in order to control borer attack successfully. Numerous

failures have been observed at mills where applications of insecticides were made carelessly or with a tendency to cut corners. Unless the recommended concentration and dosage is applied, and applied properly, the entire operation will be a waste of money and effort. Dosages and concentrations carry a safety margin, but this must necessarily be narrow to keep down the cost of treatment.

Ira Hatfield (Monsanto Chemical Company): Dr. Kowal reports that the number of requests coming into his office for information on beetle control has increased in the past few years. This increased interest has also been noted by chemical manufacturers and research workers. This is to be expected since log and lumber prices have increased and these increased costs make attention to protection of logs and lumber from insect attacks more and more important.

Two questions came to my mind as I read the manuscript. Benzene hexachloride seemed to be the most effective insecticide tested. Have you any indication as to how this product would be accepted by woodsmen and sawmill hands? Also, have lumber producers indicated any concern relative to acceptance of sprayed wood by the lumber buyers?

I think this paper is a distinct contribution to the research worker's attempts to solve a serious insect problem in the woods and drying yards.

Dr. Kowal: The timber operators with whom we have carried on cooperative tests have been very enthusiastic in their adoption of the control measures we have developed. They have been in a position to observe the effectiveness of the insecticide applications and the benefits to be derived. Many other timber operators are applying these control measures as a result of recommendations made through correspondence or other direct or indirect communication with our laboratory.

There have been no objections raised in so far as health hazards of the chemical are concerned. The precautions required in the use of any toxic have been emphasized to mill hands and accepted by them. The oil and emulsion formulations are not particularly objectionable or irritating except when pentachlorophenol is added.

We have heard no expression of concern regarding acceptance of treated wood by lumber buyers. It is conceivable that this point might arise. However, there is no cause for concern for two reasons: (1) the initial amount of benzene hexachloride on treated lumber is hardly sufficient to be hazardous to man; and (2) the insecticide would be largely dissipated by the end of six months.

Control of Stain, Mold, and Decay in Green Lumber and Other Wood Products

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Pathologist
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Pathologist
Division of Forest Pathology, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration, United States Department of Agriculture

This paper summarizes recommended seasoning practices and chemical treatments for the dipping or surface treatment of lumber and other wood products to prevent mold, stain, and decay damage during seasoning and storage. Chemical dip treatments based on chlorinated phenols and organic mercurials alone or in mixtures and in combination with such compounds as borax and soda have been successfully used for this purpose. Dip treatment of lumber when combined with recommended handling practices for logs and lumber can result in almost complete elimination of losses due to fungi during air seasoning and a great improvement in lumber quality.

Introduction

EFFECTIVE and economical methods have been devised for controlling stain, mold, and decay damage to forest products during air seasoning. These methods were generally practiced by the lumber industry prior to the last war. Many mills continued adequate control measures throughout the war and many others have since reinstated them. Nevertheless, an unnecessarily large amount of lumber on the general market is still infected with stain, mold, and decay. Stain and mold are not particularly harmful except for special uses where appearance or strength is important. What may not be generally recognized is that decay fungi thrive under the same conditions as do mold and stain fungi. Consequently, moderate to heavy stain is good grounds for suspecting the presence of decay. Even though the decay may not have progressed to a point where it is recognizable, the wood may be seriously weakened. Moreover, many decay fungi may remain dormant in dry wood for long periods and resume their destructive action if the wood again becomes wet.

If wood is to maintain its rightful place, more attention must be paid to the control of fungi. Control must start with the proper handling of logs and be carried on through the milling and seasoning processes.

Control of Stain and Decay in Logs

Logs, particularly hardwood logs, that are not immediately converted into lumber or other products are at times subject to serious degrade from the attacks of stain and decay fungi (Fig. 1). Damage is most rapid in logs cut between June and October, when the fungi are most active and ambrosia pin-hole beetles and bark beetles are most active. These beetles contribute to the fungus damage by carrying the spores through the bark and into the sides of the logs.

Where winters are relatively cold, attack by fungi is slowed down to negligible amounts in logs cut and stored between October and the following spring. In the Gulf States, however, stain and decay are not stopped completely during this period and some loss is likely if storage is longer than 3 or 4 months.

The most effective method of keeping losses to a minimum is, of course, to convert the logs into lumber or other products within a week or two. With saw logs and other large round products, decking in the open or under other conditions that hasten drying has little value in preventing fungus damage. Furthermore, rapid drying may result in excessive loss from end checking.

[1] In cooperation with the Southern Forest Experiment Station.

[2] In cooperation with the Forest Products Laboratory, maintained by the Forest Service, U. S. Department of Agriculture, at Madison, Wis., in cooperation with the University of Wisconsin.

Fig. 1.—Gum logs with heavy stain at the ends. Under certain conditions visible end stain may appear within 10 days, and the discoloration may penetrate into the log as rapidly as 1 foot per month.

Water Storage

When it is impractical to utilize logs promptly it is sometimes possible to store them in ponds, lakes, or fresh-water inlets. This is a regular practice at some sawmills and by far the safest one when long periods are involved. Experience with thousands of ponded pine logs salvaged from timber felled by the New England hurricane of 1938 indicates that even those logs that floated were protected in substantial measure against fungus attack. However, in the Gulf States logs that float high, particularly hardwood logs, often suffer severe damage to the above water parts.

Chemical Treatment

Chemical spray treatments are available that will prevent serious losses from stain and decay in logs stored for 3 to 4 months if insect attack is negligible. Bark and woodboring insects are not repelled by the commonly used fungicides and when they attack logs they may carry stain and decay fungi into the interior of logs where a surface treatment has no effect. The chemicals recommended for log sprays to control fungi are listed in Table 1.

The chemical may be readily applied with an ordinary garden spray of the sustained pressure type. One having a capacity of 3 or 4 gallons

TABLE 1.—FUNGICIDAL SOLUTIONS FOR CHEMICAL TREATMENT OF LOGS

Chemical[1]	Suggested amount per 100 gallons of water
Dowicide G (sodium pentachlorophenate)	21 lb.
Dowicide H (sodium tetrachlorophenate)[2]	21 lb.
IN-5499 (phenyl mercuric oleate)	8.5 qt.
Lignasan (ethyl mercuric phosphate)	6 lb.
Permatox 10s (sodium pentachlorophenate plus borax)	30 lb.
Santobrite (sodium pentachlorophenate)	21 lb.

[1]Materials are listed in alphabetical order and not in order of effectiveness.
The proprietary products are distributed by the following companies:
Dowicide and Permatox 10s. Chapman Chemical Co., New Orleans, La. or Memphis, Tenn.
Lignasan and IN-5499. E. I. duPont de Nemours and Co. Wilmington, Del.
Santobrite. Monsanto Chemical Co., St. Louis, Mo.
[2]In the Southern States recommended only for hardwoods.

can be readily carried by the shoulder strap. The ends and any areas where the bark is missing should be thoroughly wetted with the fungicidal solution. Logs may be sprayed either on the ground in the woods or in piles at concentration points. Woods treatment is usually preferable because it permits the log to be turned and the chemical applied to all debarked areas. Also there is likely to be less delay in treating. It cannot be too strongly emphasized that during warm weather the chemical should be applied the day the logs are cut or at latest the following day if best protection is to be secured. Under favorable conditions stain fungi can penetrate the log sufficiently in 24 hours to escape being killed by a surface application of a fungicide.

For logs cut from June to late October in the South insect attack is likely to be sufficiently prevalent to greatly reduce the effectiveness of a fungicidal solution applied alone. The Division of Forest Insect Investigations of the U. S. Department of Agriculture has found that some of the newer insecticides are quite effective in preventing insect damage to logs. There is also some evidence that these insecticides can be combined with fungicides for log treatment. So far most of the experience with the fungicides and insecticides alone or in combination has been with hardwood logs.

If control of end checking is also desired, any suitable moisture-resistant coating can be applied after the spray treatment. With certain woods in which the sapwood tends to check rather rapidly and extensively, the addition of a good end coating can also be of considerable

aid in controlling decay. This has been observed specifically in yellow and white birch, and in hard and soft maple. The deeper end checks permit entry of fungi regardless of the preservative used.

Control of Stain, Mold, and Decay in Lumber and Sawn Timbers

Methods

The surest means of preventing fungus attack on freshly cut lumber is to kiln dry it promptly. In most sections of the country during the damper periods of the summer, and in the warmer sections throughout the year, rapid air seasoning cannot be relied on to prevent stain and mold or even decay. Moreover, where rapid drying can be depended on to control fungus damage, it is not feasible with some species because of their tendency to check. Even in the arid Southwest where drying conditions are especially good, lumber is sometimes dipped so that closer piling is possible, thus reducing loss from checking. Consequently, widespread use is now made of chemical treatments for lumber which contains appreciable sapwood and which is to be air-seasoned during periods when wood-damaging fungi are most active (Fig. 2).

Economical chemical surface treatments for lumber have been developed to make it possible to use conventional seasoning piles without the usual risk of stain, mold, and decay degrade. These treatments are effective only for the comparatively short periods required for seasoning. Any chemical remaining on the stock after seasoning is largely removed by subsequent surfacing. For permanent protection it is necessary to use a wood preservative applied by a means that insures deep penetration.

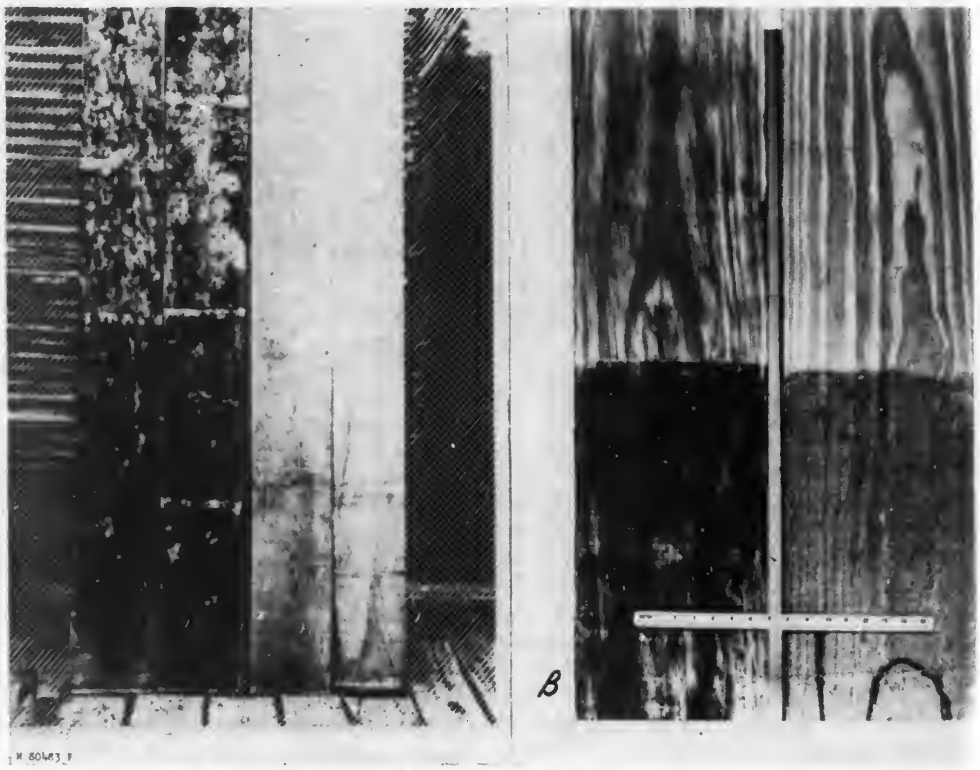

Fig. 2.—Heavily blue-stained and bright boards of (A) sweetgum sapwood and (B) southern pine sapwood. The stained and bright boards in each case were dried under practically the same conditions, the chief difference being that the bright boards were dipped.

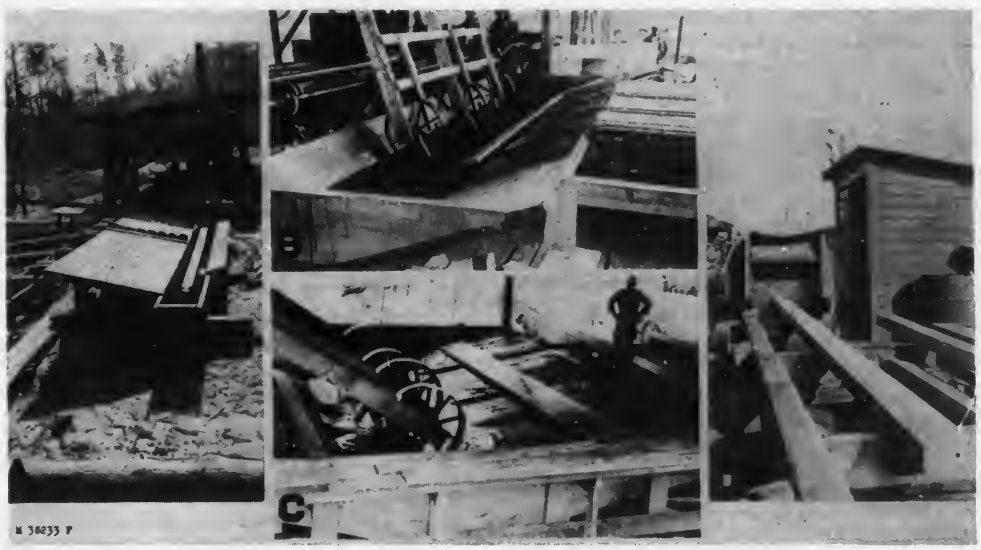

Fig. 3.—Lumber and timber treating equipment. *A*, Well-designed hand-dipping vat. Commendable features are the splashboard and ample drain apron. Cleats on the drain apron hold the boards partly on edge, thus hastening draining. *B* and *C*, Mechanical dipping vats, of simple design suited to both semiportable and large mills. Note that only a small amount of solution is needed to obtain complete coverage of the boards. *D*, Common type of mechanical timber spray.

At most mills lumber is treated by passing the freshly cut stock through a dipping vat (Fig. 3) containing the chemical in water solution. A few mills prefer to spray the chemical on, but this method must be employed with special care if thorough coverage is to be obtained, and it virtually requires mechanical equipment. At larger sawmills the dipping vat is, almost of necessity, mechanically operated, and it is placed at some convenient point in the sorting table so that the stock can be passed through it on the green chain. Overhead rolls are generally used to force the lumber into the solution (Fig. 3, B and C). At some smaller mills the dipping vat is located at a point separate from the sawmill proper and the green chain frequently is powered by a small gasoline engine. Such an arrangement is common where the lumber is dipped at a concentration yard.

At small portable and semiportable mills the stock is commonly dipped by hand, the work being done by one or two men. One man can regularly dip no more than about 5,000 feet of 1-inch lumber in a day. With power available and a mill output of as much as about 15,000 board feet per day, it is advisable to consider the use of a mechanical vat because of the great saving in labor cost. A simple portable mechanical vat may be constructed. Hand-dipping vats need be little more than sturdy wooden troughs of sufficient size to accommodate the largest boards and fitted with sloping sideboards to permit draining of the lumber and to prevent excessive waste of dipping solution resulting from splashing (Fig. 3, A). Suggestions for constructing both hand-operated and mechanical dipping vats may be obtained from companies supplying anti-stain chemicals.

Green timbers and the larger dimension materials are usually sprayed, by passing the stock on a roller conveyor through a spray box fitted with perforated pipes or special nozzles (Fig. 3, D). Excess solution is recovered and flows or is pumped back into a storage tank. At small mills large items may be treated with a hand-operated spray, sprinkling can, broom, or brush. Any of these devices is adequate so long as all surfaces are completely wetted.

The chemicals most widely used for the control of stain, mold, and decay in lumber are the proprietary products listed in Table 2.

TABLE 2.—SOLUTIONS FOR PREVENTION OF STAIN, MOLD, AND DECAY IN LUMBER

Product[1]	Suggested number of pounds per 100 gal. of water[2]	Limitations or advantages
Borax	32	Usually effective on hardwoods only.
Dowicide G	7	Not recommended for hand dipping unless special precautions are taken to protect workmen's hands[3].
Dowicide H	6	In the South recommended only for hardwoods.
IN-4400A	4	A new product not yet extensively tested.
Lignasan	2	In bulked pine and in situations where drying is particularly slow this may allow some molding.
Noxtane	10	Test results indicate that control may be somewhat inconsistent where drying is particularly slow.
Permatox 10s	10	
Santobrite	7	Not recommended for hand dipping unless special precautions are taken to protect workmen's hands[3].
Mixture 1		
Lignasan plus Dowicide G or	1	Particularly effective under severe conditions.
Santobrite	4	
Mixture 2		
Lignasan plus	½	Particularly effective under severe conditions.
Dowicide G or		
Santobrite plus	2	
Borax	6	

[1]See Table 1 for composition and source of proprietary products. IN-4400 A (ethyl mercuric phosphate and sodium pentachlorophenate) is available from E. I. duPont de Nemours and Co., Wilmington, Del. Noxtane (sodium pentachlorophenate, borax, and soda) is available from Wood Treating Chemicals Co., St. Louis.

[2]For severe seasoning conditions the proprietary products may be used profitably at a higher concentration. For timber spraying and for use on lumber that must be bulked for more than a few days, increase the concentration of all chemicals by at least one-half.

[3]Precautions for the protection of workmen's hands are given on page 488.

Most of these were also listed for log treatment, but at higher concentrations than needed for lumber. In addition to the proprietary chemicals that may be used there are listed borax, which is recommended for hardwoods only, and mixtures of two of the proprietary products, with and without the addition of borax. These mixtures have demonstrated superior effectiveness where drying conditions were poor. All the chemicals are effective in cold solution.

The cost of the solutions used for dipping 4/4 lumber averages about 15 to 22 cents per thousand board feet treated. For thicker stock the cost is less, since the amount of solution used decreases as the ratio of surface area to volume decreases.

Special Considerations for Successful Chemical Treatment

The purpose of chemical treatment should be to provide protection against fungus damage during unfavorable conditions which cannot be avoided—not to facilitate poor handling and seasoning practices. By paying attention to a comparatively few details, the most important of which are mentioned below, generally good results may be expected.

Stain-free Logs.—It is desirable that the logs be bright and free from infection at the time they are converted into lumber. The chemical affects only the surface layers of the wood; consequently infection originating in the log may continue to spread in the interior of the sawed product.

Prompt Treatment.—For best protection during warm weather, lumber should be dipped the day it is sawed or at latest the following day. Greater delays give infections a chance to go deeper into the wood than the chemical. As a result interior stain is likely to develop. During cool weather delays longer than 24 hours may do no harm; the maximum delay that can be safely tolerated with particular climatic conditions, however, can be determined only by experience. If excessive delay is unavoidable dipping is still recommended, particularly because control of the slower-growing decay fungi may still be adequate. In such cases more rapid seasoning is advisable, if practicable.

Proper Solution Concentration.—The treating chemicals should never be used at concentrations lower than those recommended by the suppliers. These concentrations have been established by numerous tests and actual mill experience and are the lowest that ordinarily can be

used with safety. On the other hand, concentrations often can be increased to advantage on thick stock or during periods of wet weather. It should be emphasized that most of the treating chemicals are used in such low concentrations that small errors in weighing may amount to large percent shortages.

Mixing Tank.—A special tank of known capacity, which at small mills need consist of nothing more than a barrel, is necessary to obtain accurate proportions of chemical and water. Do not dissolve the chemicals in the dipping vat itself. Since none of them dissolve immediately, it takes time for the solution to attain uniform strength. Moreover, the quantity of water in a dipping vat usually cannot be estimated very reliably.

Thorough Treatment.—The dipping vat should be so constructed and equipped that all stock passing through it will be completely immersed. Complete surface wetting is all that is necessary. The solution should never be allowed to become so low that occasional bunching of the stock causes top boards to go through wholly or partially untreated. Furthermore, solutions used for dipping lumber tend to lose strength with use. This weakening can be held to harmless proportions by replenishing the vat every time the solution level drops to about 80 percent of the full working level.

Stock being sprayed should be handled with extra care to insure that no surface areas remain untreated. The spray nozzles must be kept constantly free from clogging, and it is usually necessary to have considerable force behind the sprays in order that the splash created will take care of portions of the stock not directly hit by the outcoming streams. When timbers are sized after treatment they should be resprayed. Mills getting best stain control in treated timbers use stickers to separate timbers on the dock.

Protection of Treating Solution from Rain.—The dipping vat should be sheltered by a roof if at all feasible. Exposed vats should at least be covered when not in use. It takes very little rain to seriously reduce the concentration of treating solution in a vat properly constructed with drain apron and splash board. This factor is commonly overlooked in accounting for treatment failures.

Limited Bulking of Green Stock.—Surface treating of lumber is surprisingly effective in preventing fungus attack in stock bulk piled after treatment for periods of several weeks. Nevertheless, bulking reduces the assurance of good control, and treated lumber should be strip piled for seasoning as soon as practicable after sawing. If bulking beyond a few days is unavoidable the concentration of the treating solution preferably should be increased to 1½ to 2 times that ordinarily recommended for lumber and especially favorable drying conditions provided when the lumber is finally placed in the seasoning pile. If the lumber is to be kiln dried or shipped green and then kiln dried, rather than air-seasoned, the higher concentration mentioned above will ordinarily give satisfactory protection for 4 to 6 weeks.

Seasoning Pile Covers.—Pile covers may be advantageous in seasons when rainfall is prevalent. Without a roof there is danger of heavy staining in a number of the upper courses. A good roof should project about 1 foot in front and 2½ feet in the rear. If it is tightly constructed a pitch of 1 inch to the foot will shed water satisfactorily. The roof should be elevated at least 5 inches above the top layers of lumber to permit free circulation of air from the top to the bottom of the pile (Fig. 4).

Seasoning Pile Foundations.—Moderately high foundations promote circulation of air through the seasoning tile, which in turn aids in the success of the chemical treatment. The most advantageous height of foundations depends somewhat on drainage conditions in the yard and the closeness of piling. Foundations should not be obstructed by weeds or debris. For permanent locations they preferably should be constructed of pressure-treated wood or other durable material. The use of slabs in place of elevated foundations favors fungus attack. Simple temporary foundations for use by portable mills can be made from short sections of round post wood (Fig. 5).

Alignment and Spacing of Boards.—Unsatisfactory stain control in properly covered and elevated piles, following adequate chemical treatment, can almost always be overcome by more open piling. If stain occurs in spite of the treatment, the stock may be drying excessively slowly. Increasing the spacing between

Fig. 4.—A seasoning pile with boards well spaced and arranged to form continuous vertical flues that greatly aid air circulation through the pile. Blocks supporting the cover permit freer movement of air than do supports consisting of several layers of boards.

boards is probably the simplest and most effective way of increasing the drying rate.

Stickers.—For promoting drying, narrow, dry stickers obviously are preferable to stickers of green lumber. Stock stickers can be used in many cases if other seasoning practices are good and no more than four of them are placed in a course, but because they materially reduce the rate of drying they are never as safe as dry stickers. Slab stickers should never be used since the presence of bark favors not only stain occurrence but also insect damage.

Stickers commonly are a source of lumber infection. Some mills place unused stickers under cover to protect them from rain. For piling the better grades of lumber, treated stickers provide greater safety. Dry stickers dipped for 3 minutes in a 5 percent solution of sodium pentachlorophenate (Table 1) will not promote infection of the lumber and they will last longer. For untreated stickers, heartwood of a durable species is preferable.

Yard Layout.—Seasoning yards laid out to take the fullest advantage of prevailing winds are in the most favorable position for promoting drying and stain control. Piles should be situated to shield one another as little as possible from wind movements. It is important that they be placed in even, regular rows, to form continuous front, rear, and side alleys.

Fig. 5.—Short post sections, six to eight inches in diameter, make good elevated foundations for temporary use at portable mills.

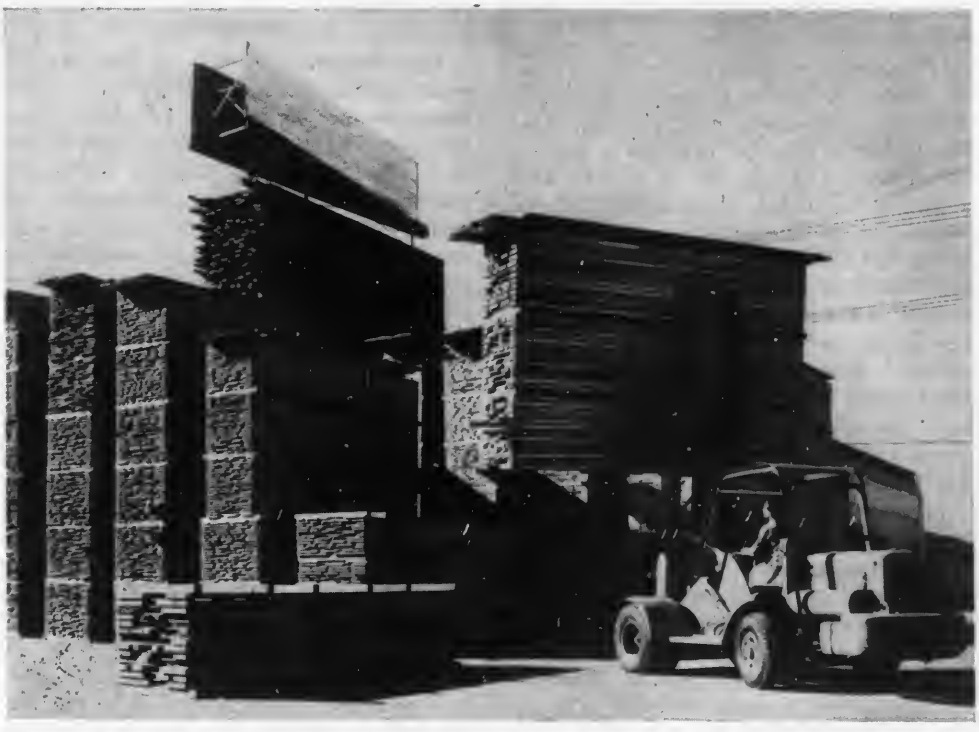

Fig. 6.—Package piling. Chemical treatment is expected to be especially beneficial in keeping boards in such piles free from fungus damage.

Tramways 16 to 20 feet wide, rear alleys about 8 feet wide, and side alleys from 2 to 4 feet wide are common at mills where chemical treatments are successfully employed.

Package Piling

Package piling, of the general type illustrated in Fig. 6, is becoming increasingly prevalent. Its flat construction retards run-off of rain water and the lack of foundation results in slower air circulation, particularly in the lower portion of the pile, than would otherwise be the case. The significance of these features with respect to potential fungus damage has not yet been established. It is probable, however, that lumber piled in this manner may be more than ordinarily benefited by dipping.

Protection of Workmen Handling the Treating Chemicals

In the dry form, all of the fungicidal products mentioned here, except borax, may cause severe burns if allowed to remain on the skin. However, no more than ordinary care is needed to avoid trouble in this respect. In solution at recommended treating concentration some of the proprietary products may irritate the skin of persons susceptible to the chemicals. This difficulty is, of course, most prevalent where the dipping is done by hand, but it also may be encountered at any point in the mill where a considerable amount of the dipping solutions remains on the surface of the stock. Usually by the time the stock reaches the seasoning yard little trouble is experienced. This disadvantage of most of the chemicals can be overcome by a few precautions that are comparatively easily managed. Ample practical evidence of this is given by the large volume of lumber that has been dipped by hand with some of the present chemicals over a period of more than 15 years. The most important precautions are:

(1) Protect the workmen with rubber gauntlets and waterproof aprons; canvas gloves or palm pads of leather or belting worn over the rubber gauntlets reduce the amount of wear and often aid in handling the stock. The gauntlets should be washed free of chemical at the end of each working period. Hooks for handling lumber in connection with hand dipping are helpful where it is practicable to use them.

(2) Carefully follow the recommendations of the manufacturer or distributor concerning the use of a particular product.

(3) For the treating work and for handling the wet stock, be watchful to discover workmen who may be allergic to the treating chemicals used, and to remove them from the hazard.

(4) While spraying logs and lumber, use particular care to keep the chemical from the face.

Control of Stain, Mold, and Decay in Other Forest Products

The measures described in this paper for the control of fungi in logs and lumber have been found applicable to other forest products. Chemical dips are used to protect such products as veneer, staves, hoops, and shingles that are to be air seasoned. The use to be made of a product, such as for food containers, should be considered in determining whether such treatments can be safely and profitably used.

Discussion

R. A. Hertzler (Southeastern Forest Experiment Station): This well-prepared paper should be read carefully by all people manufacturing either primary wood products such as lumber or using these products for further processing. It is a practical, easy-to-read presentation of facts regarding the control of stain, mold, and decay. The control measures are simple and inexpensive; most important, they are suitable for use by the small operator who cuts most of our lumber and other primary forest products.

I should like to emphasize two points mentioned by the authors. First, to be effective the chemicals must be applied soon after cutting because the chemicals will not remove stain already present nor will they kill fungi except by contact. Second, proper seasoning is essential, because the surface treatment provides protection only until the moisture content of the wood is lowered below that required for fungi to live.

In general, it is not easy to get small operators to adopt new techniques or to take the precautions necessary to assure their success. For these reasons the users of the lumber or

other wood products must take action, such as setting up and adhering to quality standards for the wood products they buy. They might well provide the small operators with other help, for good clean lumber reduces waste and benefits all users and consumers of wood products. Now that the authors have given us the control methods, the principal job is to get these into practice and this means working with the small operators.

The paper discusses only the control of stain, mold and decay in green lumber. Are there similar experiments for controlling these defects in other wood? Another related problem is the control of mold and stain of veneer in the manufacture of fruit and vegetable containers. Is anyone working on this subject?

Dr. Verrall: There is considerable work being done on the control of stain, mold, and decay fungi in seasoned lumber. Control during storage and use is essentially a problem of keeping the wood dry or when this is not feasible of using a wood preservative or a naturally durable wood. Results of our work in this field, dealing primarily with dipping or soaking treatments by the wood user, are being presented in trade journals from time to time.

A number of chemicals will control mold and stain in veneer used for fruit and vegetable containers. However, many of the common preservatives taint foods and cannot be used for this purpose. The Western Regional Laboratory is working on this problem and have recommended a wax treatment for berry boxes that is being tried commercially on the West Coast. Also, preliminary work on the treatment of picking boxes has been started at the Forest Products Laboratory.

John H. Grant, Jr.: Can prevention of stain be obtained absolutely by improved piling methods, provided stain fungi are not present in logs previously cut in the woods or infected by immersion in log ponds literally polluted by stain organisms?

Dr. Verrall: Neither antistain chemicals nor improved piling methods alone can be relied on for absolute stain control. Both must be used where climatic conditions cause slow drying. In the more arid forest regions or during the winter in the North good piling alone may suffice. End racking or triangular open cribs at times give adequate control, even in the South, but the exceptions are more frequent. A dip is usually needed also.

Mr. Grant: Does the cost figure represent only chemicals?

Dr. Verrall: The cost figures given are for chemicals only. When mechanical vats in the green chain are used, but slight additional labor is required and the total charge is little more than that for the chemical. Hand dipping requires additional labor, making the total cost considerably more.

Mr. Grant: Why is it generally indicated that lumber cut between September and May does not stain if properly piled?

Dr. Verrall: Lumber cut between September and May is not inherently less stain susceptible. However, during this period the weather may be cool to cold resulting in less growth of stain fungi and less staining.

BUSINESS MEETING

The meeting was called to order by President Garratt at 2:00 p. m. on Wednesday, May 4, 1949.

1. Minutes of Previous Meeting

Announcement was made that the minutes of the preceding annual business meeting, held in Chicago, Illinois, on March 23, 1948, had been approved by the Executive Board and published in the Proceedings of the 1948 National Meeting.

2. Report of the Secretary-Treasurer

During the fiscal year 1948, the net paid-up membership of the Forest Products Research Society increased from 1197 to 2014. This increase was made up of 575 voting and associate members, 65 supporting members, and 177 student members, bringing the totals for these classes of membership to 1708, 129, and 177, respectively. The Society now has members in 47 states, the District of Columbia, Hawaii, Alaska, and Puerto Rico, all provinces of Canada, and 23 foreign countries. The following foreign countries were added to the roster during 1948: Brazil, Denmark, Honduras, Italy, Mexico, and Palestine.

The number of local sections has increased from 3 to 7, with the addition of the Virginia–Carolinas section, the Georgia–Florida–Alabama section, the Northern California section, and the Inland Empire section. All of these sections are active and have had at least one meeting. The Eastern Canadian and Deep South sections recently received approval and are in the process of organizing.

During the fiscal year one of the significant steps made, effective June 1, 1948, was placing the Secretary-Treasurer on a full time basis. Following the resignation of T. R. C. Wilson, who had been serving in a part-time capacity, Charles E. Van Hagan was engaged. The secretarial and clerical requirements of the national office in Madison, Wisconsin, are handled by one full-time and one half-time secretary.

The cash on hand April 1, 1948, was $4,799.25; total receipts during the F. Y. 1948, $50,569.75; total expenditures during F. Y. 1948, $42,667.36; and cash on hand March 31, 1949, $12,701.64.

The principal items of income were as follows: membership dues, 66 percent (38 percent for F. Y. 1948 and 28 percent for F. Y. 1949); publications, 26 percent (21.7 percent from advertising and 4.3 percent from sale of Proceedings and preprints); and meetings, 7 percent (2.2 percent advance income from the Third National Meeting).

The principal items of expense were as follows: publications, 37.3 percent; office expenses, 15.3 percent; salaries, 12.2 percent; membership campaign, 10.6 percent; national meetings, 8.8 percent; and national office rental, 8.5 percent. The remaining 7.3 percent was for miscellaneous items.

In addition to the cash on hand of $12,701.64, the Society has assets of $652 in accounts receivable, and $235 in equipment and supplies. The Society has 1326 copies of Volume 1 and 1362 copies of Volume 2 of the Proceedings valued at $8,000.

On motion duly made and seconded the report was accepted.

3. Auditor's Report

The auditor's report for the period from April 1, 1948, through March 31, 1949, was accepted by the Executive Board, and the Secretary-Treasurer instructed to print and distribute it to the members of the Society.

4. Section Activities

The President reported that four sections (Florida–Georgia–Alabama, Inland Empire, Northern California, and Virginia–Carolinas) had been organized and activated since the last annual meeting, and that the Executive Board had recently approved the formation of two additional sections (Eastern Canadian and Deep South).

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TYPE 250-2—ready mixed (hardener incorporated) cold-setting urea resin glue for assembly gluing on all types of furniture, plywood, and other wood products.

TYPES 107-2 and 121-2—(hot-setting) urea resin glues for plywood and general bonding work on hot-press equipment. Type 107-2 is recommended for limited extension with wheat flour, while Type 121-2 is highly extensible.

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A meeting of representatives from each of the nine sections was held on May 3, and recommendations relating to section activities and relationships with the national organization were prepared for submission to the Executive Board. It was also announced that the Executive Board had voted to establish an Advisory Council, comprised of two representatives of each active section, to meet annually during the national meeting.

5. Exploratory Committee

The President announced the formation of an Exploratory Committee, comprised of representatives of organizations interested in forest products research, created for the purpose of considering possible cooperative action on the part of the participating agencies. Membership on this Committee is as follows:

George M. Hunt, *Chairman,* representing Forest Products Research Society

Frank J. Hanrahan, Wood Industries Division, American Society of Mechanical Engineers

Herbert B. McKean, Division of Forest Products, Society of American Foresters

D. B. Mabry, American Wood Preservers Association

G. M. Magee, American Railway Engineering Association

L. J. Markwardt, Committee D–7 on Wood, American Society for Testing Materials

William A. Oliver, Committee on Timber Structures, American Society of Civil Engineers

6. Report of General Chairman of the Grand Rapids Meeting Committee

An unofficial count showed that there were 655 paid registrations for the technical sessions of the 1949 National Annual Meeting. Thirty-six states, Canada, Puerto Rico, Mexico, England, Hawaii, the Netherlands, India, Norway, and Switzerland are represented. At the Forest Products Industry Show, 76 exhibitors used 126 booths to display their products. It was estimated that more than 3000 people have gone through the Forest Products Industry Show during the 3-day meeting.

The chairman thanked the members of the Committees for their excellent work in making this meeting such a success and expressed the hope that the Society would return to Grand Rapids for another national meeting as early as possible. The members of the committees were as follows:

General chairman:

Jac. H. Tigelaar, Haskelite Manufacturing Co.

Reservations and Registration:

George D. Meier, *Chairman,* Haskelite Manufacturing Co.
E. Lago, Fine Arts Furniture Co.
J. H. Christy, Imperial Furniture Co.
J. H. Vander Vennen, Vanderley Bros. Furniture Co.

Exhibits:

A. H. Stuart, *Chairman,* John Widdicomb Co.
W. E. Martin, Grand Rapids Varnish Co.
S. W. Tamminga, Hekman Furniture Co.
F. Atkinson, Perkins Glue Co.

Arrangements:

J. Bergsma, *Chairman,* Bergsma Brothers
C. Hancock, Borden Company
J. B. Imrie, Imrie Dry Kiln Co.
J. D. Quist, Chemist (Consultant)

Signs and Artwork:

R. H. Dingman, *Chairman,* Klok Institute
J. C. Killebrew, Forest Products Laboratory
D. G. C. Perry, Klok Institute

7. Report of the Abstracting Committee

Your chairman takes full responsibility for the delay in starting the abstracting service. In building a program of this type, it is essential to keep mistakes to a minimum and each step must be thought out and agreed upon in advance by all members of the Abstracting Committee, and some of the steps must naturally have the approval of your officers. The magnitude of the start of the service was a matter of most thorough discussion and was deliberately kept small in order to keep costs in bounds and to avoid initiating a larger program than the Society could maintain. In this we believe we have been particularly successful. We are for-

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tunate in having the services of the following volunteer abstractors:

F. W. Guernsey	A. J. Snyder
E. S. Harrar	A. W. Stout
J. E. Lodewick	L. C. Wallace
G. G. Marra	W. B. Wallin
A. J. Panshin	F. F. Wangaard
N. V. Poletika	R. W. Wellwood
G. J. Ritter	W. W. Varossieau

The Society and this Committee owe these gentlemen a sincere vote of thanks for being willing to serve without fee and to take on this pioneering job with no thought of reward other than having offered to perform a worthwhile service to their fellow workers.

Assignment of periodicals to be abstracted presented a particularly troublesome problem, but it was early agreed that the most inaccessible literature should be assigned first and that for the initial period we should very sharply limit our abstraction to the direct subject "forest products." As the program grows and our affluence increases, the abstracting will be extended to the many other worthwhile periodicals in related fields of endeavor.

The abstracting assignments are as follows, in the order of their agreed-upon importance:

General Russian
General German
General European
Australian Timber Journal
Wood (English)
Reveue Internationale du Bois
Timber of Canada
Paper Trade Journal
Quarterly Journal of Forestry
Canada Lumberman
Lesnaya Promishlenost
Holztechnik vereinigt mit Sperrholz
Lesochimicheskya Promishlenost
UNASYLVA
Forest Products News Letter
Timber News

To date there have appeared seven abstracts. These, as you know, have been published in the *Monthly Bulletin,* beginning with the January 1949 issue. The Committee's appreciation goes particularly to Messrs. Guernsey, Poletika, Preston and Wangaard for the work in getting the program underway.

The work to date has been done with the expenditure for subscriptions of only about $25.00, the cost of subscriptions to six journals. The only other funds spent on this project have had to do wiith that part of the Secretary's office costs which may rightly be assigned to editing the abstracts. Thus, we believe we have brought the program to a successful starting point with a very minimum of drain on our Society. We also believe that we have laid a foundation which can grow uniformly and logically.

At this time the Abstracting Committee would welcome all constructive comments and suggestions for operation during the coming year that the membership may wish to furnish.

Respectfully submitted,

R. M. BROWN
I. H. ISENBERG
J. E. LODEWICK
A. J. PANSHIN
G. J. RITTER
C. B. HEMMING, *Chairman*

On motion duly made and seconded the report was accepted with thanks to the Committee Members.

Discussion

W. W. Varossieau (Central Institute for Testing Materials, The Hague, Holland): Relating to the work of the Abstracting Committee, the following points may be considered:

1. A list of abstracted journals should be issued from time to time.
2. It should be indicated whether these journals are abstracted exhaustively or inexhaustively so as to inform the user of the abstracts whether the information taken from a given journal is complete or not.
3. The abstracts should be published in a given sequence following a classification system. The speaker recommends for this purpose the Universal Decimal Classification (U.D.C.) sponsored by the International Federation for Documentation.
4. Indexes to abstracts should be prepared in order to increase the accessibility of the information they contain. Without in-

this

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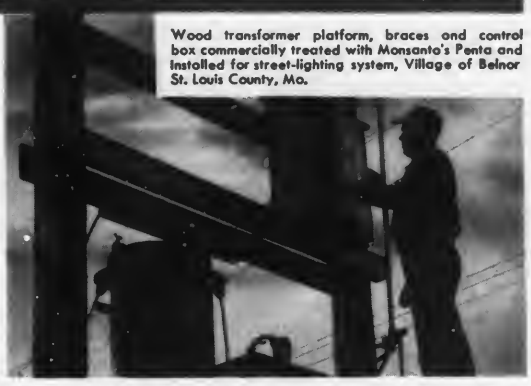

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dexes the effort put into preparing abstracts is made in vain.

5. The abstracting program of the F.P.R.S., should be brought in line with the W.N.E.S.C.O. program on Coordination of abstracting journals.

8. Report of Publications Committee

The Publications Committee is glad to report on this occasion regarding its activities during the past year.

As in the first year of our existence, the Publications Committee has not been able to function in the manner that seemed desirable to the Chairman or to the Executive Committee. Part of the reason for this is probably the fact that the Forest Products Research Society is a new group and in any new group developments are such that it is usually not possible to carry out activities as outlined or according to schedule. Because of the deadline that we have always had to meet in editing, preparation of the style standards, and other activities of the Publications Committee, we have not had an opportunity to function as a unit. In this situation it has been necessary for the chairman to assume most of the responsibility for getting the work of the Committee done without in most cases being able to consult Committee members. This has been the case particularly in connection with the preparation of Volumes 1 and 2 of our Proceedings and in the review of papers preparatory to preprinting them for this meeting. To have attempted to circulate papers to Publications Committee members would have resulted in failure to meet the deadlines which had been set up.

The job of editing and preparing the papers for preprinting has been considerable and the task has been made quite a bit more difficult by the fact that although we have a set of style standards prepared by the Publications Committee not all of the individuals invited to present papers on this program followed the suggestions included in the Standard. This is an item that definitely needs to be corrected in the future.

As a result of the experience of the Publications Committee during the past two years, we recommend to the Society and Executive Committee:

1. That a deadline or due-date of not less than two months prior to the date of meeting be placed on all papers. By setting such a deadline it will be possible for the Committee really to function as it was intended to do. It does not seem to this Committee that the setting of such a deadline would work hardship on authors and it would result in much improved presentation as well as facilitate editing.

2. We recommend further that when the papers are received by the Secretary they be sent by him to one of the members of the Publications Committee, the assignment to be made on the basis of field interest of the Committee member or assignment agreed on by the Secretary and the Chairman of the Committee. Upon completion of the review by the Committee member the paper will be sent to the Chairman of the Publications Committee for final review and then to the Secretary for further editing and preprinting. It is felt that in this way a better manuscript can be presented to the printer with consequent reduction in final printing costs.

3. It is recommended that copies of the FPRS Style Standards be sent to all individuals invited to present papers at FPRS meetings or all individuals agreeing to prepare manuscripts. It is felt that this is the only possible way by means of which some uniformity can be obtained in the style of papers submitted for publication in the Proceedings. As you may recall, we have purposely kept our Style Standards so simple and unencumbered by detail that it should not be a burden for anyone, whether preparing a general paper or one based on individual research, to follow the standards. Unless we follow this procedure and insist on a reasonable degree of conformity with our Style Standards, the work of the Publications Committee will always be unnecessarily heavy and the costs of preprinting and printing because of lack of uniformity in detail of papers will be higher.

4. The Publications Committee suggests that the Executive Committee consider the value of preprinting papers and the effect of the availability of such preprints on attendance and participation in meetings. It seems to the Publications Committee that it would be desirable to re-evaluate this whole situation and consider whether preprints are necessary or desirable and

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PUBLICATIONS COMMITTEE
E. A. BEHR
J. B. GRANTHAM
F. S. VOGEL
F. H. KAUFERT, *Chairman*

On motion duly made and seconded the report was accepted with the compliments and appreciation of the Society for a job well done.

9. Report of Committee on Coordination of Forest Products Research

The report of this Committee was presented and discussed at Technical Session V. Upon motion by C. D. Dosker, duly seconded, the acceptance of this report was voted by the meeting. The report will be published with the papers of Technical Session V.

10. Report of Resolutions Committee

Upon motion of the chairman of the Resolutions Committee, the following resolutions were adopted by the meeting:

(1) Recognizing that much of the success of this Third Annual Meeting of the Forest Products Research Society is the result of a great deal of planning and hard work by the responsible committees and in particular by the Grand Rapids Meeting committees.

Be it resolved that the Society hereby acknowledge its appreciation to the members of these committees for their excellent work.

(2) In appreciation of the services that they have rendered to the Forest Products Research Society during their period in office.

Be it resolved that the gratitude of the Society be extended to the following outgoing officers and regional board members:

Robert A. Cockrell
Jac. H. Tigelaar
Fred W. Gottschalk

(3) The Society records with regret the loss through death during the past year of the following members:

Jack M. Bedford
Grant Dixon, Sr.
H. D. Marshall
F. X. Neuhaus
Herbert S. Phillipson
G. Victor Treyz
E. A. Throckmorton

Be it resolved that this expression of sympathy to the families and friends of these men be included in the permanent records of this meeting.

RESOLUTIONS COMMITTEE
E. SIGURD JOHNSON
DON W. WALTERS
FREDERICK F. WANGAARD, *Chairman*

11. New Business

No new business was presented.

12. Report of Tellers Committee

As the result of the balloting for officers for the Forest Products Research Society for 1949–50 the following were declared elected:

For *President:* Edward G. Locke, Portland, Oregon
For *First Vice President:* James F. Hamilton, Lansdale, Pa.
For *Second Vice President:* Roy M. Carter, Raleigh, N. C.
For *Northeast Regional Board Member* (2-year unexpired term): C. F. Van Epps, Rochester, N. Y.
For *North-Central Regional Board Member* (3-year term): Ralph H. Bescher, Orrville, Ohio
For *Southwest Regional Board Member* (3-year term): L. J. Carr, Sacramento, California

Attested by the Tellers Committee:

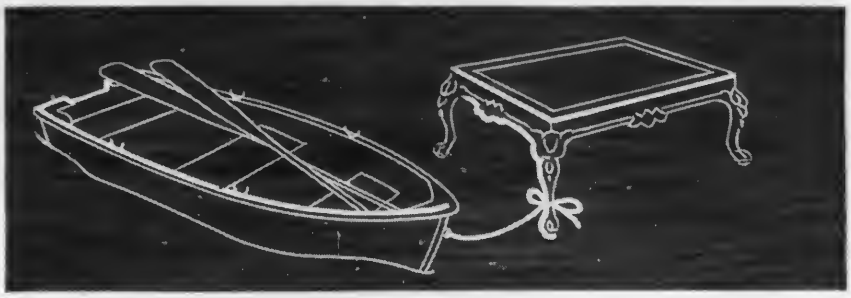
HERBERT W. ANGELL, *Chairman*
ELDON A. BEHR
ALFRED H. BISHOP
ELLWOOD S. HARRAR
O. HARRY SCHRADER, JR.

13. Installation of Officers

On assuming charge of the meeting, the newly elected president, Edward G. Locke, expressed to the retiring president, George A. Garratt, the appreciation of the membership of the Society and the Executive Board more particularly for the excellent leadership and many hours which he had devoted to the Society during the past year and made a report on plans for the next National Meeting, to be held in Portland, Oregon, June 25–29, 1950.

14. Adjournment

The meeting was adjourned at 3:00 p. m.



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FOREST PRODUCTS INDUSTRY SHOW

For the first time in the history of the forest products industry, manufacturers of woodworking machinery and equipment and allied products gathered together to display their wares at the Forest Products Industry Show, sponsored by the Society in conjunction with the 1949 National Annual Meeting. An outgrowth of the table-top exhibits held as an added feature of earlier national meetings, this show took on major proportions, with more than 1½ million dollars worth of equipment brought from all parts of the country. An estimated 4,000 persons passed through the show during the three days and nights that it was open; admission was free to the public as well as to members and guests attending the technical sessions. The exhibit floor of the Grand Rapids Civic Auditorium was sold out as 76 companies took 126 booths for their displays. The majority of the machines were in operation so that visitors could actually watch them go through their paces—something never before possible.

The companies that had exhibits in the Forest Products Industry Show were:

The Louis Allis Co.
Milwaukee 7, Wisconsin

American Cyanamid Co.
New York 20, N. Y.

E. C. Atkins and Company
Indianapolis, Indiana

Ballantine Industries
Newark 2, New Jersey

Bell Machine Company
Oshkosh, Wisconsin

V. Berthelson Engineering
Joliet, Illinois

Borden Company, Chemical Div.
New York 17, New York

Buss Machine Works
Holland, Michigan

Cam-Lock Corporation, Division of Western Automatic Machine & Screw Co.
Chicago, Illinois

Hugh Courtright and Company
Chicago 19, Illinois

Crescent Machine Foundry & Supply Co.
Rockwell Manufacturing Company
Leetonia, Ohio

Curtis Machinery Corp.
Jamestown, New York

Delmhorst Instrument Co.
Boonton, New Jersey

DeLux Saw & Tool Company
Chicago, Illinois

DeWalt, Inc.
Lancaster, Pennsylvania

G. M. Diehl Machine Works, Inc.
Wabash, Indiana

Durex Plastics & Chemicals, Inc.
North Tonawanda, New York

Ekstrom–Carlson Company
Rockford, Illinois

Elmendorf Research Company
Chicago, Illinois

Gardner Dowel Company
Gardner, Massachusetts

Grand Rapids Dry Kiln Co.
Grand Rapids, Michigan

Grand Rapids Varnish Co.
Grand Rapids, Michigan

Greenlee–Mattison Sales Co.
Rockford, Illinois

Handy Manufacturing Co.
Chicago 25, Illinois

W. S. Hawker Sons Mfg. Co.
Dayton 2, Ohio

Earle Hart Wood Working Machine Co.
Chicago 6, Illinois

Hart Union
Chicago, Illinois

Curt G. Joa, Inc.
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Kaydel Moisture Gauge
New York 6, New York

Kirk and Blum Manufacturing Co.
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GARDNER DOWEL CO.
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PISTON TYPE
FEED CHAIN and TRACK

Lumber Drying Specialties Co.
Grand Rapids, Michigan

Mall Tool Company
Chicago, Illinois

Marcoloy, Inc.
Springdale, Connecticut

Mereen–Johnson Machine Co.
Minneapolis, Minnesota

Marion Machine Foundry
Marion, Indiana

Michigan Pattern Works
Grand Rapids 3, Michigan

Midwest Manufacturing Co.
St. Louis 19, Missouri

Moisture Register Co.
Alhambra, California

Monical Machinery Company
Grand Rapids, Michigan

Monsanto Chemical Co.
Springfield, Massachusetts

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Bristol, Tennessee

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Grand Rapids, Michigan

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Chicago, Illinois

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Red Lion, Pennsylvania

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Benton Harbor, Michigan

Smithway Machine Company
Seattle 8, Washington

Standard Dry Kilns Company
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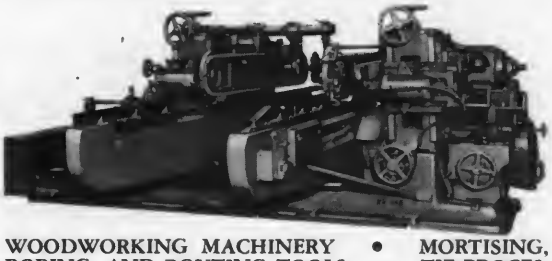

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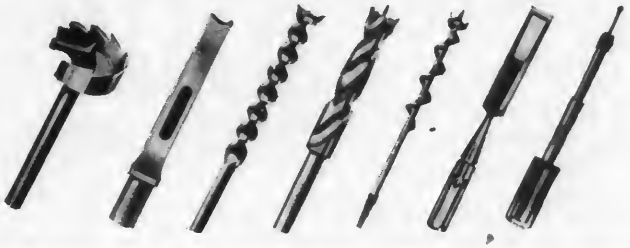

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John L. Hill, Student, Yale School of Forestry
S. K. Swamy, Student, Yale School of Forestry
F. F. Wangaard, Yale School of Forestry

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Peter A. Rahaim, Gardner Dowel Company

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Glen Harris, Monsanto Chemical Company

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Manchester
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W. Burdette Wilkins, Consulting Engineer
Rudolph Willard, Consulting Engineer

Riverton
E. E. Bergey, National Casein Company
Robert Cousins, National Casein Company

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Kenneth G. Wooden, Setter Brothers, Inc.

Herkimer
Robert E. Treskow, Remington Rand

Jamestown
Willard V. Fichtel, Union-National, Inc.

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C. W. Johnson, American Cyanamid Company
Anders Kjellgren, American Defibrator, Inc.
Jacques Kohn, Balsa Ecuador Lumber Corp.
E. L. Kropa, Borden Co., Chemical Division
Paul H. Kruse, Merritt Monsanto Corp.
W. F. Leicester, The Borden Co., Chemical Division
Paul H. McCormack, National Adhesives
Julius Marashinsky, Balsa Ecuador Lumber Corp.
Eugene R. O'Hare, 206 East 30th Street
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Harry Hull St. Clair, Hart Moisture Gauges, Inc.
Theodore Steinway, Steinway & Sons
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C. F. Van Epps, Stronberg-Carlson Company

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WOOD-LOK comes ready-to-use. It remains in a usable liquid form for months — not 3 to 4 hours. No cooking, heating or mixing. It provides a humidity-resistant bond which is a *durable* resin joint. Its bond is resilient, not *brittle*. It resists sharp impacts. WOOD-LOK adheres wood, Formica and Masonite. It can also be used for compressed air doweling.

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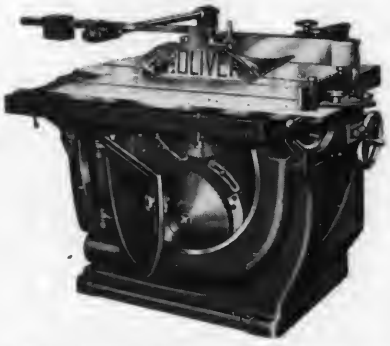

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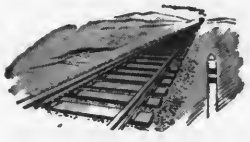
Some Common Sense ABOUT WOOD PRESERVATIVES



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When and if a better preserving method is developed, to the point where it can be recommended to large users of lumber, Barrett will sponsor it. At present, upon the basis of our half-century of wood-preserving experience, we unqualifiedly recommend Creosote oil as the most reliable safeguard of your lumber investment.

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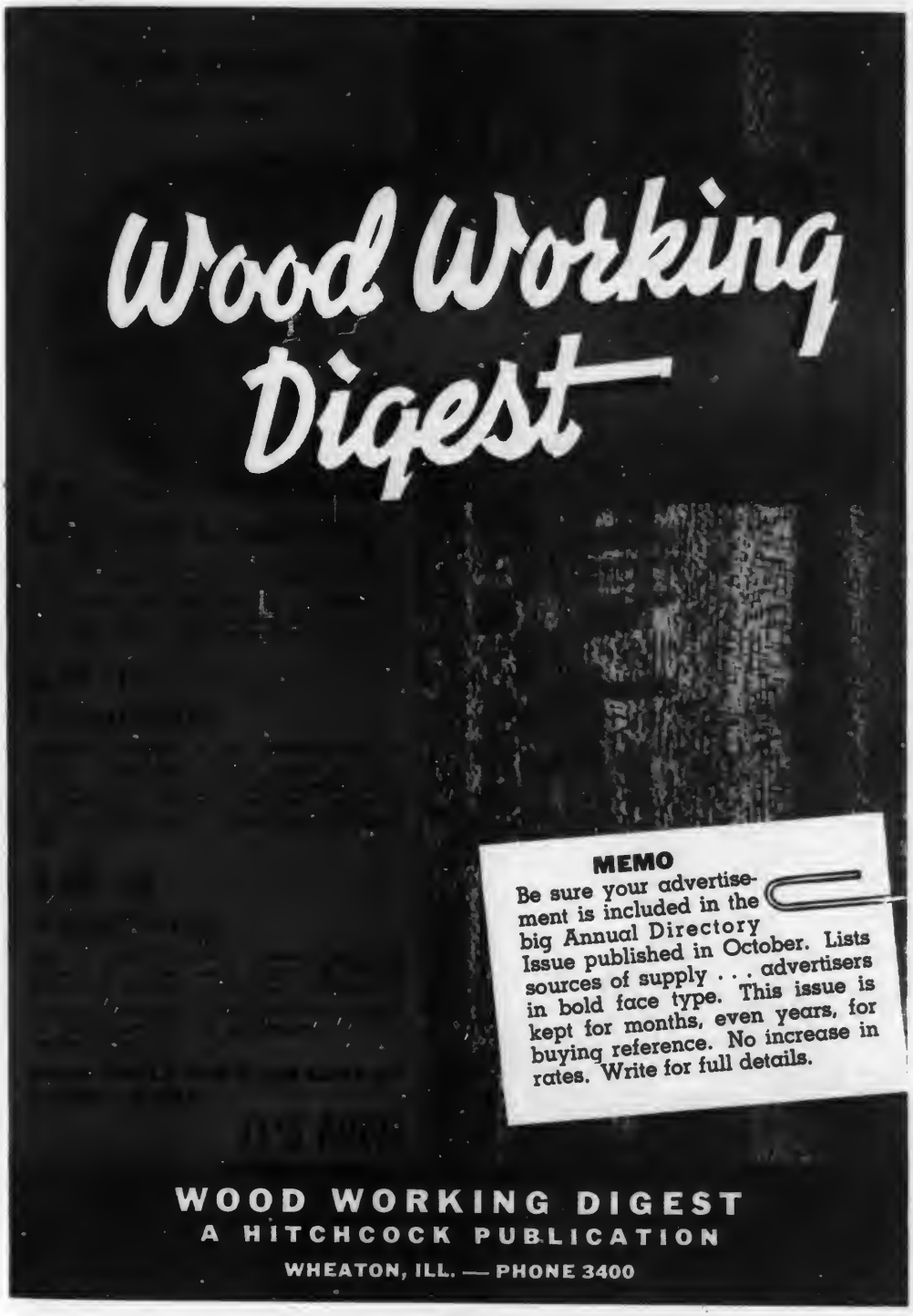
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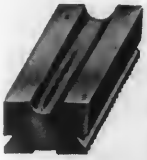

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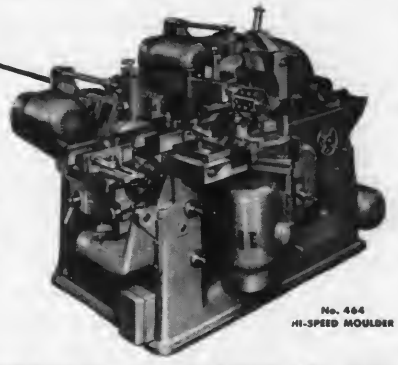

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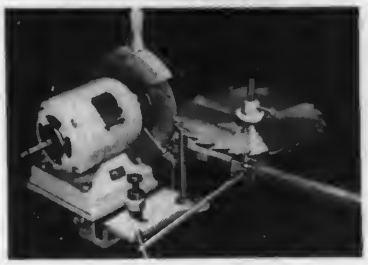

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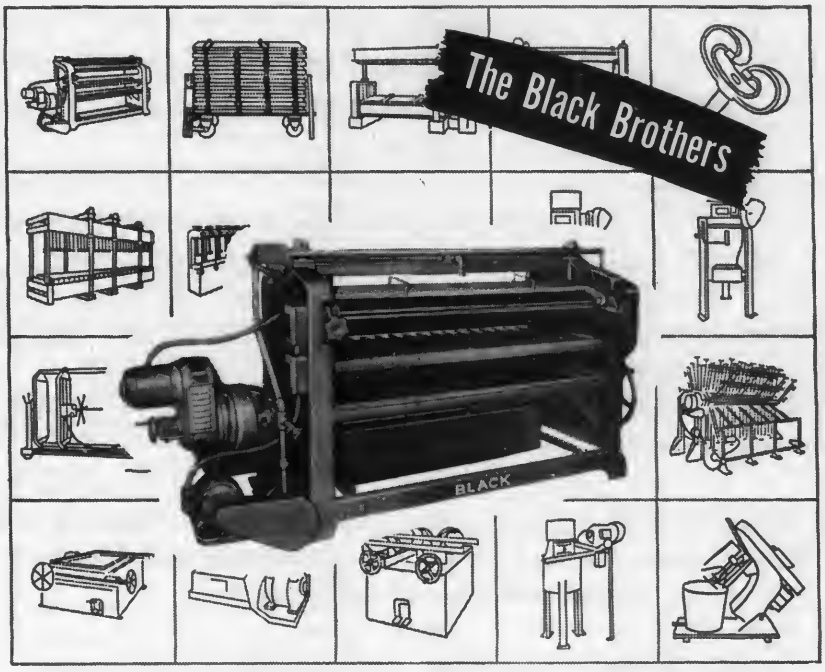

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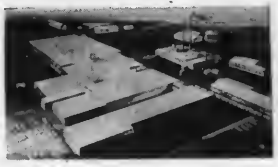

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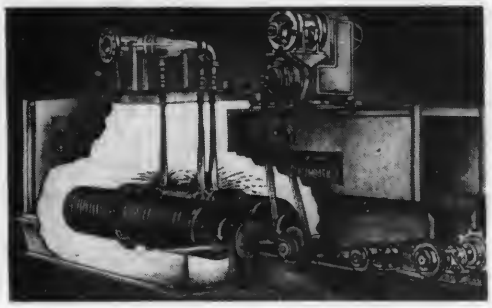

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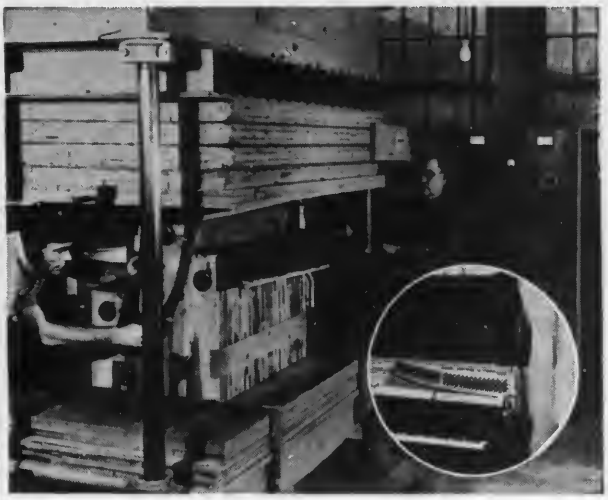

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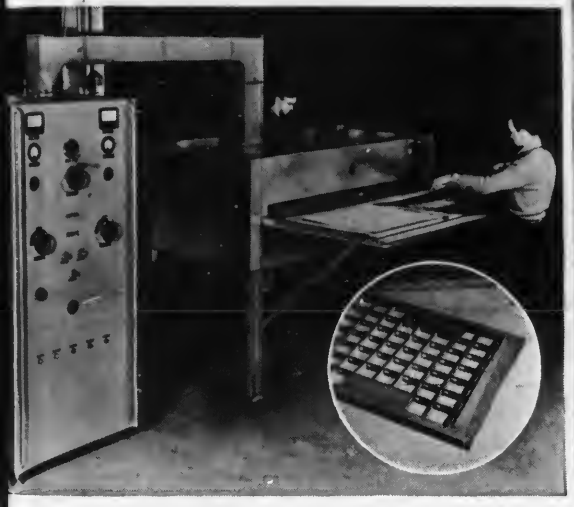

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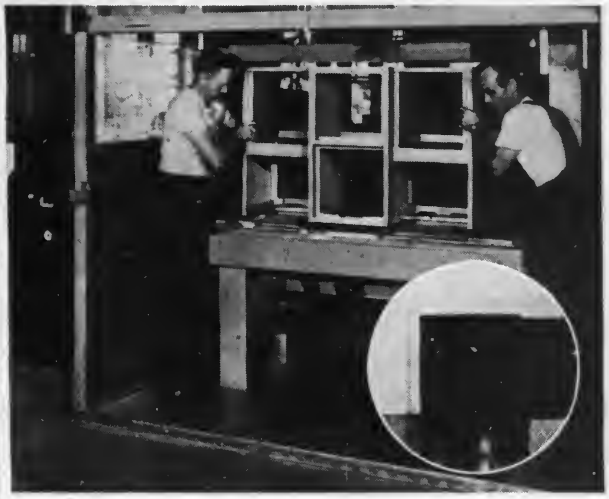

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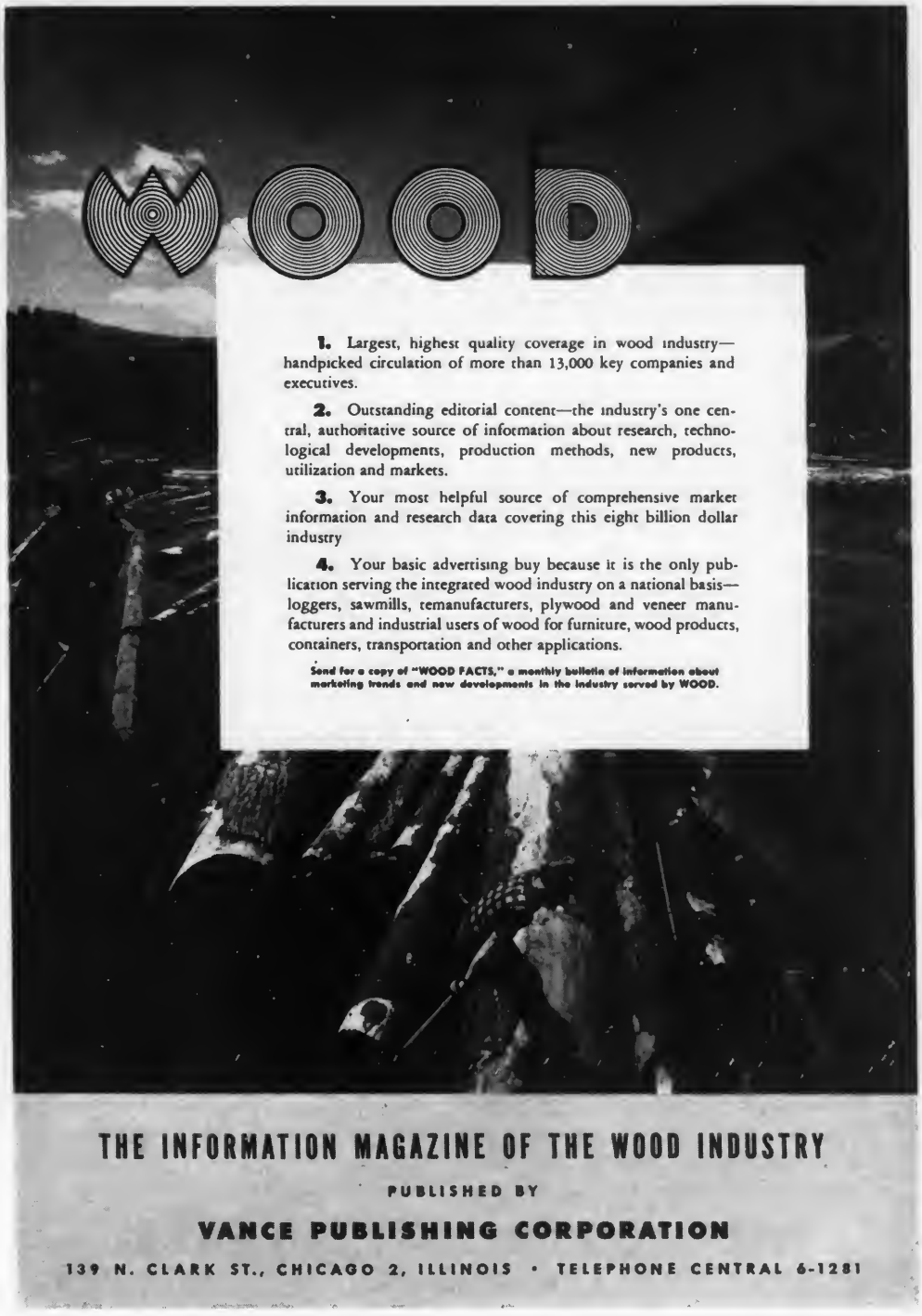
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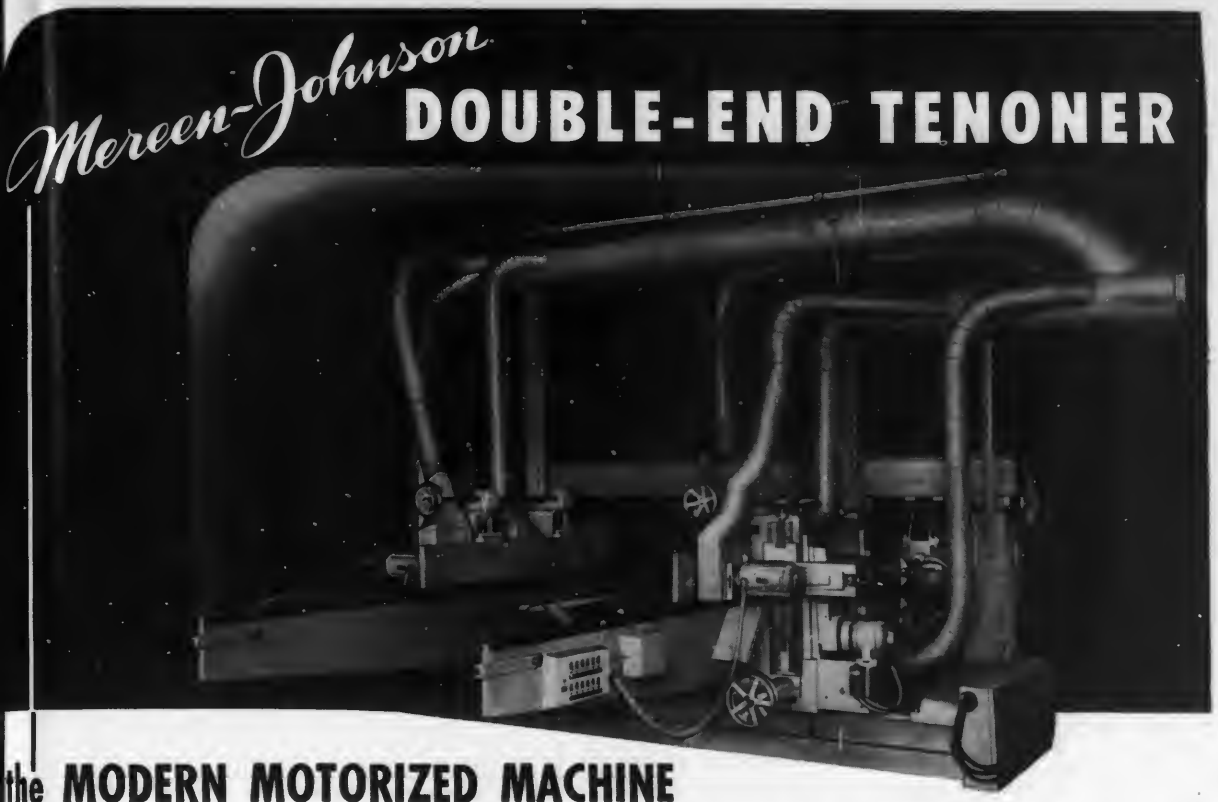

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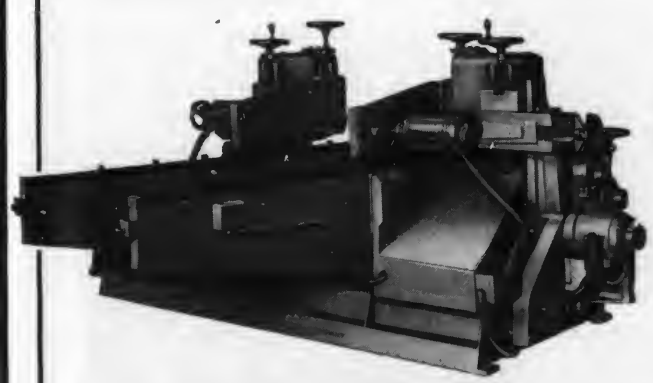

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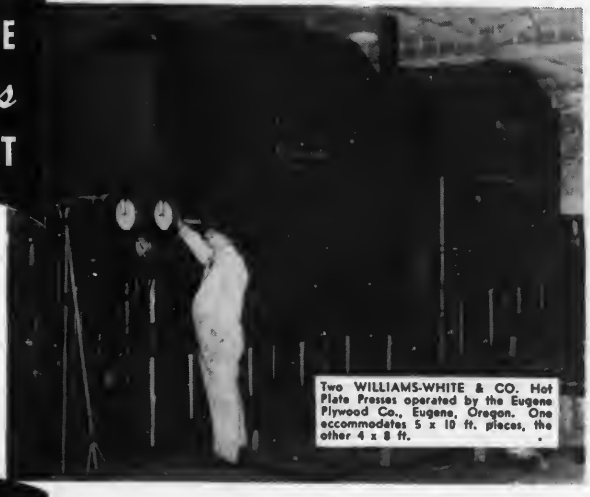

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The moisture measurement is based ***on electrical conductance,*** which varies with moisture ***percentage,*** and ***not on electrical capacitance,*** which varies with the ***weight*** of water content. Therefore the density of wood, whether hickory or the lightest balsa, has negligible effect upon the meter reading. ***Corrections for species are seldom more than a small fraction of the indicated percentage, and usually may be disregarded except for the closest of determinations.*** If the measurement were based on capacitance, which varies with weight and not percentage of moisture, the same meter reading would indicate quite different percentages depending on the density of the wood—far higher percentages for light species than for dense species. And even in the same piece of wood the denser parts would read higher than the lighter parts.

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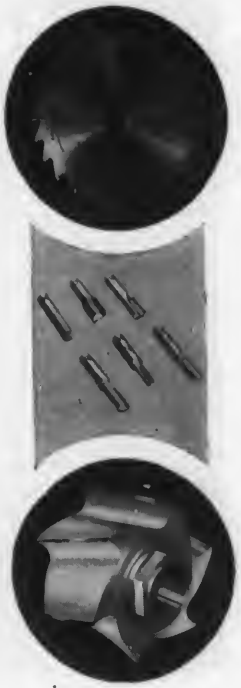

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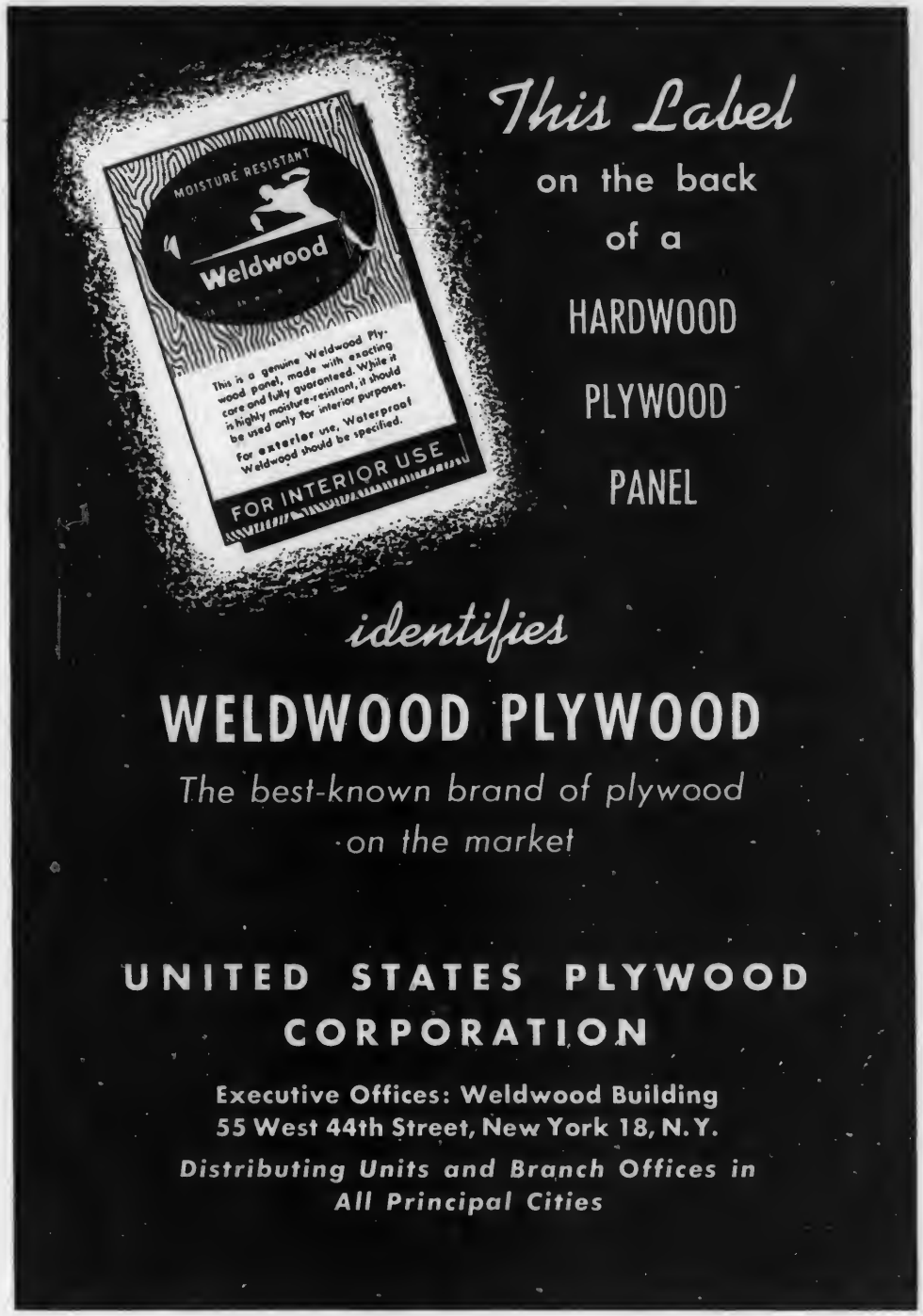
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